CERTIFICATE OF MAILING 37 C.F.R. 1.8 (a)

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail in an envelope on the date indicated, addressed to the Commissioner for Patents, Mail Stop Amendment, PO Box 1450, Alexandria, VA 22313-1450.

07-25-2005

Date

Terrie Lindquist

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of: Gavrel et al.	Confirmation No. 6530
Serial No.: 10/706,002	Examiner: Frank M. Lawrence Jr.
Filed: November 11, 2003	Group Art Unit: 1724
For: **HIGH PRESSURE PROCESS AND APPARATUS FOR THE ELECTROCOAGULATIVE TREATMENT OF AQUEOUS AND VISCOUS FLUIDS**	Attorney Docket No. 0271KR.44551

DECLARATION OF GUS GAVREL AND IRA VINSON UNDER 37 C.F.R. §1.131

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Tom Gus Gavrel and Ira B. Vinson hereby declare as follows:

1. Tom Gus Gavrel, Ira B. Vinson and David Wayne Otto (jointly "we") are the co-inventors of the above referenced patent application relating to a plate and frame reactor design. The above referenced patent application claims priority from a provisional patent application filed November 11, 2002. We conceived and reduced to practice, or moved with due diligence toward actual reduction to practice of, the subject matter of Claims 1-19 of our above referenced application prior to October 10, 2002.

2. Under a duty of confidentiality, Gus Gavrel disclosed certain information regarding our plate and frame reactor design to Mr. Bill Gilmore on April 20, 2002, at the Texas Water 2002 Trade Show in San Antonio, Texas. Ira Vinson witnessed the disclosure in person, and David Otto witnessed portions of the disclosure audibly by telephone. At the time, Mr. Gilmore was the owner of a provisional patent application having U.S. Patent Application No. 60/329289 filed October 12, 2001, that did not teach a plate and frame reactor design. Mr. Gilmore subsequently filed a non-provisional application on October 10, 2002, which claimed priority to the provisional application filed October 12, 2001, and included new information regarding a plate and frame reactor design that was very similar to the information that we disclosed to him at the Trade Show.

3. Exhibit #1 of this Declaration is a copy of the Gilmore provisional application. Exhibit #2 of this Declaration is a copy of the Gilmore nonprovisional application.

4. Our conception of the above-referenced apparatus coupled with reduction to practice or reasonable due diligence to actual reduction to practice are evidenced by the attached Exhibits #3-7, each of which are dated earlier than October 10, 2002.

5. The attached Exhibits include: (i) a copy of a fax sent September 20, 2002, by one of the inventors to his attorney containing drawings of the invention, including a drawing of a plate and frame apparatus on page 002 of the fax, as Exhibit #3; (ii) an email sent by one of the inventors to his attorney on September 20, 2002, describing a process and apparatus for the electrocoagulative treatment of aqueous and viscous fluids utilizing a plate and frame apparatus, as Exhibit #4; (iii) an email sent by one of the inventors to his attorney on October 1, 2002, describing a preferred embodiment of the plate and frame electrocoagulation apparatus, as

Exhibit #5; (iv) an email sent by one of the inventors to his attorney on October 4, 2002, describing a plate and frame electrocoagulation apparatus, as Exhibit #6; and (v) an email sent to one of the inventors by his attorney containing a draft of a patent application for a plate and frame apparatus for electrocoagulative treatment of aqueous and viscous fluids, as Exhibit #7. We understand that attorney-client privilege may apply to these documents. We hereby waive such privilege for these specific documents, but no others, for the purpose of establishing the facts set out in this Declaration.

6. In summary, we conceived the subject matter of Claims 1-19 of the above-referenced patent application in the United States and reduced to practice or moved with reasonable due diligence to a subsequent actual reduction to practice each of Claims 1-19 prior to October 10, 2002.

7. We further declare that all statements made herein of our own knowledge and all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful and false statements and the like so made are punishable by fine or imprisonment or both under § 1001 of Title 18 of United States Code and that such willful and false statements may jeopardize the validity of the above-referenced application and any patent issuing therefrom.

FURTHER DECLARANT SAYETH NOT.

Tom Gus Gavrel — Date 7/25/05

Tom Gus Gavrel

Ira B. Vinson — Date 7/25/05

Ira B. Vinson

CERTIFICATE OF MAILING 37 C.F.R. 1.8 (a)

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Date 07-25-2005

Terrie Lindquist

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of: Gavrel et al.	Confirmation No. 6530
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For: **HIGH PRESSURE PROCESS AND APPARATUS FOR THE ELECTROCOAGULATIVE TREATMENT OF AQUEOUS AND VISCOUS FLUIDS**	Attorney Docket No. 0271KR.44551

DECLARATION OF DAVID WAYNE OTTO UNDER 37 C.F.R. §1.131

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

David Wayne Otto declares as follows:

1. Tom Gus Gavrel, Ira B. Vinson and David Wayne Otto (jointly "we") are the co-inventors of the above-referenced patent application relating to a plate and frame reactor design. The above referenced patent application claims priority from a provisional patent application filed November 11, 2002.

2. Under a duty of confidentiality, Gus Gavrel disclosed certain information regarding our plate and frame reactor design to Mr. Bill Gilmore on April 20, 2002, at the Texas Water 2002 Trade Show in San Antonio, Texas. Ira Vinson witnessed the disclosure in person. I witnessed portions of the disclosure audibly by telephone. At the time, Mr. Gilmore was the owner of a provisional patent application having U.S. Patent Application No. 60/329289 filed October 12, 2001, that did not teach a plate and frame reactor design. Mr. Gilmore subsequently filed a non-provisional application on October 10, 2002, which claimed priority to the provisional application filed October 12, 2001, and included new information regarding a plate and frame reactor design that was very similar to the information that we disclosed to him at the Trade Show.

3. We conceived the subject matter of Claims 1-19 of the above-referenced patent application in the United States and reduced to practice or moved with reasonable due diligence to a subsequent actual reduction to practice each of Claims 1-19 prior to October 10, 2002.

4. I further declare that all statements made herein of my own knowledge and all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful and false statements and the like so made are punishable by fine or imprisonment or both under § 1001 of Title 18 of United States Code and that such willful and false statements may jeopardize the validity of the above-referenced application and any patent issuing therefrom.

FURTHER DECLARANT SAYETH NOT.

David Wayne Otto

7/25/05
Date

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07-25-2005
Date

Terrie Lindquist

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of: Gavrel et al.	)	Confirmation No. 6530
Serial No.: 10/706,002	)	Examiner: Frank M. Lawrence Jr.
Filed: November 11, 2003	)	Group Art Unit: 1724
For: **HIGH PRESSURE PROCESS AND APPARATUS FOR THE ELECTROCOAGULATIVE TREATMENT OF AQUEOUS AND VISCOUS FLUIDS**	)	Attorney Docket No. 0271KR.44551

DECLARATION OF CONSTANCE GALL RHEBERGEN

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Constance Gall Rhebergen declares as follows:

1. I am the attorney of record for the above referenced patent application.

2. I hereby verify that Exhibits #3-7 which accompany the Declaration of Gus Gavrel and Ira Vinson Under 37 CFR §1.131 submitted herewith are true and correct copies of documents that were kept in the ordinary course of business by our law firm, Bracewell and Giuliani LLP.

3. I further declare that all statements made herein of my own knowledge and all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful and false statements and the like so made are punishable by fine or imprisonment or both under § 1001 of Title 18 of United States Code and that such willful and false statements may jeopardize the validity of the above-referenced application and any patent issuing therefrom.

FURTHER DECLARANT SAYETH NOT.

Constance Gall Rhebergen July 25, 2008

Constance Gall Rhebergen Date

Exhibit A

Provisional Patent Application of F. William Gilmore
for "Electrocoagulation Reaction Chamber and Method"

Check for filing fee -- $80
Provisional Cover Sheet -- 1 page
Fee Transmittal -- 1 page
Specification - 16 pages
Drawings -- 8 sheets

Provisional - 10/12/01

JC857 U.S. PTO
60/329259
10/12/01

This is Bill Gilmore's original provisional filing, filed before our disclosure to him in April, 2002, at the Trade Show in San Antonio. He subsequently added our disclosure to this provisional filing (filed for Utility Patent on 10 October 2002).

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No.	EL651444755US

INVENTOR(S)

Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)
F. William	GILMORE	Denver, Colorado

☐ *Additional inventors are being named on the ______ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Electrocoagulation Reaction Chamber and Method

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☑ Customer Number [ ] *Type Customer Number here* → Place Customer Number Bar Code Label here: 26092 PATENT TRADEMARK OFFICE

OR

☐ Firm or Individual Name					
Address					
Address					
City		State		ZIP	
Country		Telephone		Fax	

ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages*	16	☐ CD(s), Number	
☑ Drawing(s) *Number of Sheets*	8	☑ Other (specify)	Postcard
☐ Application Data Sheet. See 37 CFR 1.76			

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status. See 37 CFR 1.27.
☑ A check or money order is enclosed to cover the filing fees
☑ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 06-0788
☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): $80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.
☑ No.
☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______

Respectfully submitted,

SIGNATURE [signature]

Date 10/12/2001

TYPED or PRINTED NAME Kyle W. Rost

REGISTRATION NO. *(if appropriate)* 27943

TELEPHONE 720-528-8863

Docket Number: GIL 1012

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Electrocoagulation Reaction Chamber and Method

TECHNICAL FIELD

The invention generally relates elements used in electrical and wave energy chemistry. More specifically, the invention relates to electrolytic apparatus composed of electrodes with an electrode supporting means consisting of a dielectric gasket or spacer. In a further aspect, the invention relates to an electrolytic apparatus and method that employ parallel plate electrodes to form plural separate treatment chambers or zones, with a feeding or withdrawing means providing a flow of liquid to be treated to the cells.

BACKGROUND ART

The practice of electrolysis upon aqueous solution results in production of water and an agglomerate. The latter can be separated from the water to produce a clean water. This process and its chemistry are well known, and many types of apparatus are used in the practice of it.

A primary problem in using an electrolytic process to produce clean water is a generally high cost of treatment. The direct cost of electricity is a significant part of the overall cost. The amount of electricity used in electrolytic processing is variable according to many factors in the design of an electrolytic reaction chamber. Design features that reduce electrical consumption are beneficial.

The cost of maintaining electrodes is another part of overall cost. Electrodes are consumed by the electrolytic reaction, but their consumption is basic to the chemistry of the reaction and is expected to occur over a predetermined time that is a function of reaction conditions. However, electrodes also can be fouled or short-circuited by deposit of reaction products. A fouled electrode becomes prematurely inefficient and can add to the amount of electricity consumed. Also, it will wear unevenly and will require premature

replacement or removal for cleaning, either of which adds to maintenance cost and down-time for the reaction chamber. A reaction chamber that keeps its electrodes clean during electrolytic processing is beneficial.

A reaction chamber is designed to accommodate many aspects of the electrolytic process. Primarily, the chamber must be effective and efficient in its performance. Thus, such aspects as electrode composition, spacing, and surface area are considered. Sustainable spacing between electrodes is important, so that adjacent electrodes do not contact each other and thereby produce a short circuit. The flow path through the electrodes is a significant factor, as the length of the path influences the speed with which the reaction must be performed and, thus, influences the electrical requirements of the chamber. Ease of replacing electrodes is significant, both in terms of maintenance cost and the down-time of a reaction chamber. These are only a few of the considerations that influence design of reaction chamber, which is a complex process.

One desirable configuration for a reaction chambers is known as the "filter press" design. Electrode plates are interleaved with dielectric spacers and gaskets to form an electrode stack. The stack is capped at its opposite ends by end plates, which are clamped together by suitable bolts or the like. The bolts are tightened to clamp the end plates, in turn squeezing together the elements in the stack of electrodes, gaskets and spacers. The filter press design is desirable because the stack of electrode plates is a unit that is easy to handle. Further, the spacing between plates is well controlled. The end plates can be configured for connection to inlet and outlet conduits for feeding and removing a process liquid, and the electrode plates can be suitably apertured or otherwise configured to define a flow path between the electrodes in the stack. A filter press design leads itself to the use of electrode plates having a square or rectangular shape, which is easily fabricated and, therefore, relatively low in cost.

United States Patent No. 1,541,947 to Hartman et al (1922) shows an early attempt at constructing such a filter press style reaction chamber. The electrodes are rectangular plates. Alternate plates are apertured near opposite narrower ends of the rectangle. Notably, two apertures are used at the perforated end of each rectangle. These apertures are transversely oblong, such that a considerable percentage of the perforated end is open

for liquid flow from one processing chamber or zone to the next. Thus, the stack the electrodes defines a sinuous, longitudinal flow path from edge-to-edge of the rectangle, with the direction of flow reversing in each successive zone as the process liquid flows through the series of processing zones.

Later advances in chamber design reveal that edge-to-edge sinuous flow across a rectangle is not uniform. Fluid in certain areas between the electrodes will be stagnant, allowing precipitates to foul nearby surfaces of the electrodes. United States Patent No. 4,124,480 to Stevenson discloses this problem in a filter-press design that employs edge-to-edge flow over rectangular plates in a stack. The electrode plates are slotted across the full width of alternating narrow ends to encourage the process liquid to flow over the full width of each electrode plate. However, even passing through a full width slot, the liquid stagnates along the edges of the plates, perhaps because of resistance induced by contact with the gasket or spacer located at such edges. Thus, it appears likely that longitudinal flow over a rectangular plate bounded by a side wall will be non-uniform and will result in fouling of certain areas of the plates.

The Stevenson patent also proposes a filter-press design using an alternate flow pattern with square electrode plates forming square treatment chambers. A first group of electrode plates are apertured at their center. A second group of electrode plates are relatively smaller in size than the first, such that they leave an almost continuous peripheral gap between each of the second group plates and the stack gaskets. In the second group, only the corners of the periphery are engaged between the gaskets and secure the second plates in the stack. The plates of the two groups are arranged in the stack in alternating sequence. The resulting flow path is from the center of a plate in the first group to the periphery of a plate in the second group, and vice versa.

However, it can be readily seen that such center-to-periphery and periphery-to-center flow will be non-uniform when square treatment chambers are used. In a stack of square plates, the shortest flow path, and likely the one with least resistance, is between the center hole of one plate and the midpoint along any of the four edges of a juxtaposed plate. Fouling is likely along the relatively longer flow paths near the corners of all plates in the

stack, with resulting uneven wear, poorly predictable process control, higher electricity usage, short circuits, and premature plate replacement or maintenance.

It is evident that circular plates would be no more successful in producing equal length radial flow paths. Fabricating and assembling a stack of circular plates is likely to be more expensive and will not solve the problems of premature fouling. Like square plates, circular plates must be configured with portions that engage the stack gaskets; and they must provide apertures or peripheral gaps that establish a sinuous flow path between plates. A circular shape is little better than a square one in meeting these two requirements. Uneven flow paths or stagnant areas are inevitable results. Circular plates are likely to behave similarly to square plates in suffering prematurely fouled areas.

It would be desirable to overcome the existing fouling problems in reaction chambers of the filter-press design. In particular, it would be desirable to have a chamber design producing predictable wear patterns in which fouling is not a substantial issue. Such a design would enable the reaction chamber to be operated with sustained process efficiency over a predictable interval. Such a predictable interval can be determined by calculating the consumption of the electrodes according to the reaction parameters imposed upon the chamber, rather than by the unpredictable time between loss of efficiency due to fouling. Maintenance or replacement operations can be performed at scheduled intervals, allowing a high degree of confidence that the electrocoagulation process will remain effective and efficient between such service.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as embodied and broadly described herein, the electrocoagulation chamber and method of this invention may comprise the following.

DISCLOSURE OF INVENTION

The objects, advantages and novel features of the invention shall be set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by the practice of the invention. The object and the advantages of the invention may be realized and attained by means of the instrumentalities and in combinations particularly pointed out in the appended claims.

The accompanying drawings, which are incorporated in and form a part of the specification illustrate preferred embodiments of the present invention, and together with the description, serve to explain the principles of the invention. In the drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of the overall electrocoagulation process.

Figure 2 is top plan view of a single electrode plate, showing the corner apertures in solid border, and showing an alternative central aperture in dashes.

Figure 3 is a top plan view of a single gasket or spacer.

Figure 4 is a side elevational view of an entire reaction chamber.

Figure 5 is a side elevational view of top and bottom pressure plates of a reaction chamber, showing compression members joining the pressure plates.

Figure 6 is a simplified exploded view of a portion of a reaction chamber, showing the alternating placement of electrode plates.

Figure 7 is a schematic view of the liquid flow path through a reaction chamber.

Figure 8 is a schematic view of the liquid flow path through a single treatment chamber of zone within a reaction chamber, showing the four corner apertures in one of the bordering electrode plates in dashed outline and showing the central aperture of a second bordering electrode plate in solid outline.

BEST MODE FOR CARRYING OUT THE INVENTION

The invention provides a non-fouling, self-cleaning, sinuous flow, electrolytic reaction chamber. A reaction chamber having a filter press structure is suitable for establishing and maintaining a stack of electrode plates that define a plurality of sequential treatment chambers or processing zones. The filter press style of reaction chamber is suited use in a system for treating water or other process fluids by electrocoagulation. The non-fouling characteristic of the reaction chamber is achieved by creating streamlined flow paths confining the process liquid to a highly predictable or known flow path through each zone. Thus, in a streamlined flow path, the available surface area of the electrodes is

limited to the shape of a predictable or known flow path characterized by a lack of stagnant areas.

The surface areas of the electrode can be conformed to the predictable or known flow path by several methods. First and preferred, the electrode plate is supplied in a size exceeding the size of the known or predictable flow path, and those portions exceeding the flow path are blocked. For example, the electrode plate may be generally square, which is not a desirable shape for a flow path and, therefore, contains surplus area.

The portions of the plate not a part of the predictable or known flow path are blocked from contact with the process liquid. Such blocking may be accomplished by supplying a gasket cut into a configuration that lies over the portion of the plate to be blocked. If a spacer is used in combination with a gasket between juxtaposed plates, the spacer may be cut in the same shape as the gasket so that it will support the gasket against the plate. When a stack of electrode plates, gaskets and spacers are compressed in a filter press style reaction chamber, the gaskets are snugly compressed against the plates, forming a liquid tight seal. The remaining, unblocked surface areas of the electrodes are in contact with the process fluid. Because the unblocked areas bound a known or predicted flow path, the unblocked areas are self-cleaned by the liquid flow. A second method of conforming the surface area of the electrode to the predictable or known flow path is by providing the electrode plates in the size and configuration of the flow path. For example, a flow path over a plate with apertures located in certain predetermined areas will define a predetermined shape. The electrode plates in a reaction chamber employing such a flow path can be cut in a matching size and predetermined shape, with supporting tabs or an additional edge portion at the periphery, as required to be engaged by gaskets. The gaskets and spacers are shaped to engage only the additional edge portions or supporting tabs of the specially shaped plates.

Empirical testing can determine the shape of flow paths in a reaction chamber. Initially, a reaction chamber employing electrode plates of a standard shape, such as a square, can be operated for a sufficient time to determine where fouling occurs. Such testing should be conducted with plates configured to define apertures in preselected locations and of size and spacing suited for process conditions. The flow paths appear on

the plates as clean areas, while areas prone to stagnation or low flow rates will be coated with deposits. The results of empirical testing establish the known or predictable flow paths for the reaction chamber. Thereafter, the gaskets and spacers can be shaped to block the plate areas not lying along the empirically determined flow path.

The invention provides a reaction chamber employing a flow path having a pattern causing the process fluid to clean the exposed electrode surfaces. The reaction chamber is of filter press construction, in which electrodes are arranged in a stack. As assembled in the stack, each electrode has a native geometric shape or outer edge contour that can be chosen for any desired characteristic, such as a physical shape suited to form a leak-proof stack, a shape that is convenient to fabricate and handle, or a shape that otherwise meets a requirement of a particular situation. Plates of regular symmetrical geometric shape relative to a center point tend to be good choices for sealing in a filter press chamber, easy handling, economy of manufacture and shipping, efficiency in utilization, and for forming predictable, regular flow paths. By way of example, such shapes include an equilateral triangle, square, circle, or other regular geometric shape. Elongated variations of these shapes, such as an ellipse, oval, rectangle, or an irregular shape are less desirable but are useable because the flow path ultimately will be determined by other factors, such as the relative positioning of apertures in juxtaposed plates.

A gasket separates each electrode from a juxtaposed electrode in the stack. Each gasket can be shaped at its outer edge to match the outer contour of the electrode plate. Optionally, each pair of juxtaposed electrodes are separated by two or more gaskets, and a spacer of predetermined thickness is interposed between two of the gaskets. The gaskets and spacers are planar and are of similar or substantially the same shape, such as if cut from sheet stock by the same cutting die. The gaskets lie generally over the peripheral margin of each electrode plate and have an open center area, which defines the uncovered central areas of each juxtaposed pair of electrodes. The uncovered area of the electrodes is the active area that contacts process liquid and participates in an electrolytic reaction with the process liquid. The uncovered area between each pair of electrodes constitutes a separate treatment chamber or zone.

A means for establishing an electrical connection to each electrode plate allows each plate to carry a polar charge. For example, a conductive lug may extend from one or more edges of each square plate to beyond the outer edge of the gasket, providing a connection point for an electrical source. Adjacent plates may be oppositely charged by a D.C. electrical source, with the result that each treatment chamber or zone is defined by one positively charged plate and one negatively charged plate.

The electrodes define apertures allowing process liquid to pass from one zone to the next in the stack of electrodes. Each end of the electrode stack is capped by an end plate or pressure plate. The opposite pressure plates are joined together by elongated bolts, threaded rods, or other means for drawing the pressure plates toward each other. The pressure plates compress the electrode stack, primarily by compressing the gaskets to form a leak proof seal against the plates and spacers. The stack of electrode plates, gaskets, spacers and joined pressure plates together defines a reaction chamber. The pressure plates provide inlet and outlet fittings for transmitting process liquid through the reaction chamber. The apertures in the plates provide a flow passage for the process fluid to follow through the reaction chamber.

The apertures through the electrode plates establish a flow path passing sequentially through each of the treatment chambers or zones established between juxtaposed plates in the electrode stack. The flow pattern between sequential apertures is determined by the aperture positions and the configuration of the active or exposed electrode surfaces.

The plates in the stack consist of at least two groups, in which each group is configured with a different aperture pattern from the other group. The plates of the first group, or group one, each define a central and preferably circular aperture, located near the geometric center of the electrode plate. The plates of the second group, or group two, each define a plurality of peripheral apertures, preferably circular in shape.

In a plate shaped with corners or distal points, such as a square or triangular plate, an efficient usage of electrode plate area suggests locating one of these peripheral apertures near each of the corners or points of the electrode plate. Thus, in a square electrode plate, four peripheral apertures are used with one in or near each corner of the square.

In a circular plate or other plate without corners or points, the peripheral apertures are located near the peripheral edge of the plate. Preferably the peripheral apertures are equidistant from each other and from the center of the plate.

Plates of the two groups are arranged in alternating sequence in the electrode stack. Each treatment chamber or zone is bounded by one plate having a central aperture and one plate having a plurality of peripheral apertures. The flow path from zone to zone passes sequentially through the alternating hole patterns. Thus, in one of the zones the direction of liquid flow is from the center aperture of a plate from group one, spreading outwardly to the multiple peripheral apertures of a next sequential plate in the stack, which is from group two.

As the fluid enters the next zone, the direction of flow reverses. The flow pattern converges inwardly toward the center of the next sequential plate in the stack, which is from group one. This flow pattern of diverging and converging shape is repeated through the stack of electrode plates. The flow pattern causes turbulent flow of the process liquid, which encourages self-cleaning of the electrodes. The reversal of directions contributes to turbulent flow, which assists in cleaning the electrode plates and improves reaction speed and efficiency.

The almost every situation, the area of the aperture in a group one plate is expected to be unequal to the sum of the areas of the plural apertures in a group two plate. Consequently, the process liquid will undergo changes in velocity as it moves from one treatment chamber to the next. These velocity changes further contribute to turbulent flow.

The configuration of the inner edges of the spacers and gaskets is designed to block stagnant areas or areas of relatively low flow rate, such that the flow rate cannot sustain a clean condition of the electrode surfaces. Empirical testing shows that the inner edge of the gasket should have an undulated shape, consisting of trough portions and crest portions. The inner edge of the gasket defines a recess or concave trough at each of the peripheral apertures of a group two plate. The trough or recess is centered along the outside edge of one of the peripheral apertures. Thus, the number and positions of the troughs is equal to the number and positions of the peripheral apertures.

The contour of each trough portion tracks the outermost edge of a peripheral aperture up to about one-half the circumference of the aperture. The remaining half of an aperture's circumference is the inner most edge. This edge is open toward the center of the treatment chamber to allow process liquid to flow from the peripheral aperture of a group two plate toward the center aperture of a group one plate.

Neighboring trough portions of the undulated gasket edge are joined by a crest portion. Between troughs, the inner edge of the gasket defines a convex edge or crest centered on the central aperture of a group one plate. The apex of the convex edge typically will be spaced from the edge of the center aperture. A suitable spacing can be determined by the process of empirical testing. Often the crest will be separated from the central aperture by two or more diameters of the central aperture.

With reference to Fig. 1 of the drawings, a system 10 for treating a process liquid by electrocoagulation can employ a filter press style reaction chamber 12 using streamlined flow paths. On the upstream side of the chamber, the system can include a surge tank 14; a means for supplying chemical enhancement additives 16; and an ozone generator or oxygen source 18. On the downstream side of the chamber 12, the system can provide a development tank 19. In addition, the system is powered from a D.C. power supply 20 and controlled by a programmed processor such as a program logic controller (PLC) 22. In addition, the system may include supplemental standard equipment such as valves (V) and pumps (P) as required.

In a representative system, surge tank 14 holds a minimum of five minutes supply of process liquid, based on the applicable flow rate through the system. The surge tank contains a static mixer 24 for ensuring that any chemical additives 16 are thoroughly mixed with the process liquid. An ozone diffuser 26 or an oxygen micro-bubbler 28 are located near the bottom of the tank.

Chemical enhancement additives 16 commonly are acid or caustic solution for altering the pH of the process liquid. A metering pump 30 is controlled by a pH probe 32 in the surge tank for blending the acid or caustic chemical additives into the process liquid. Other additives can be added by a pump 34 controlled by a timer in the processor.

The ozone generator or oxygen source 18 is used to accelerate the oxidation rate of the electrolytic reaction. It also treats contaminants that may not be adequately treated in the reaction chamber. It is sized according to the flow rate of the system. Oxygen increases the overall oxidation rate of the electrolytic process. When ozone is used in place of oxygen, the rate of the overall oxidation reaction is increased by a factor of about thirteen. However, oxygen is less expensive and adequate for many applications.

With general reference to the drawings, a reaction chamber 12 can be constructed of square electrode plates alternating between group one plates 36 and group two plates 38. The group one plates have an aperture 40 at the center, while the group two plates have four apertures 42 distributed with one in each corner. The areas of the holes 40,42 are calculated to cause a pressure differential so that the velocity of the process liquid varies and causes turbulent flow as its passes between juxtaposed plates.

The plates are separated by spacers 46 formed of a chemically inert material such a polyvinylchloride. The spacers are selected for their predetermined thickness, which establishes a corresponding gap between the electrodes. A wide variety of spacer thickness can be preselected to accommodate the electrical requirements of the process liquid.

A gasket 48 is located between each plate and spacer for sealing the treatment chambers or zones 50 within the electrode stack. The gaskets and spacers are shaped by their inside edges to define streamlined flow paths in each treatment chamber 50. Gasket material typically is of a durometer in the range from sixty to seventy to produce a liquid tight seal without requiring adhesive. To a small degree, the gaskets influence the gap between electrodes. In addition, gaskets can be chosen with a preselected thickness to change the electrical characteristics of the reaction chamber.

The electrode stack is held in place by upper and lower pressure plates 52. The plates are equipped with fittings 54 for attaching inlet and outlet conduits to the chamber. The plates 52 are held together and compressed against the electrode stack by suitable compression rods that may include bolts, threaded rods, cam-locking fastener rods and the like. A set of four compression bolts 56 may connect the plates 52 at the four corners of the stack. In addition, another compression means such as a cam-locking fastener 58 may interconnect the plates 52 at the midpoint of each straight side of the stack. The periphery

of each electrode plate, gasket and spacer may be apertured to be threaded over the compression rods as an aid to the assembly of the electrode stack.

Each electrode plate carries a lug 60 for receiving a D.C. electrical connection. The lugs extend outside the gaskets on the outer surface of the electrode stack. A guard or cover can be placed over the reaction chamber to prevent inadvertent contact with the lugs or any other electrified portion of the reaction chamber. As a safety measure, the guard may be equipped with an interlocking switch for shutting off power to the system when the guard is removed.

The development tank 19 receives treated process liquid under pressure from the reaction chamber 12. The treated liquid resides in tank 19 while floc forms. A static mixer 64 in tank 19 enhances floc development. A polymer injection system 66 can be used where polymers will improve the settling process.

The D.C. power supply 20 receives A.C. power from the grid and transforms it to D.C. through a rectifier. The positive and negative sides of the D.C. supply are selectively connected to electrode blades in the reaction chamber. The D.C. supply can switch or reverse polarity to the electrodes. Periodically reversing polarity minimizes any buildup of oxides on the electrodes.

Overall system control resides in the program logic controller 22. Controlled features include liquid flow rate, operation of pumps and valves, and application of power to the reaction chamber electrode plates.

In operation, the system 10 is suited to treat process liquids, which may include waste water, drinking water, or process water. Process liquid is pumped from a source 62 to the surge tank 14 at a specified number of gallons per minute. The surge tank provides flooded suction for a feed pump 68. It also receives chemical additives 16 such as acid or caustic solution to adjust the pH of the process liquid. The static mixer 24 blends the additives and the process liquid. Ozone or oxygen 18 are injected into the process liquid to enhance the normal rate of oxidation that will take place in the reaction chamber 12.

Optionally, polymers can be injected into the liquid in the surge tank to improve the floc structure of certain process streams. For example, when thickening a stream of

sewage sludge, five percent of the normal polymer rate improved the resulting solids from seventeen percent to over twenty percent.

The process liquid from the surge tank is pumped under pressure through a connection to one or more reaction chambers 12. Each reaction chamber contains electrode plates formed of selected metals to provide the optimum ions for the appropriate chemical treatment of the process liquid. If multiple reaction chambers 12 are connected to the surge tank, individual reaction chambers can be placed on-line or off-line by suitable valves 67. This allows adjustment for varying flow rates and permits maintenance of individual chambers while processing continues in another chamber. The power supply 20 provides DC current to the electrodes, where the electricity passes through the process liquid and causes chemical reactions tending to form impurities into precipitates and flocs.

The treated process liquid is exits the reaction chamber and enters the development tank 19 while still under pressure. A residence time in the development tank allows floc to develop and be separated from the remaining portion of the treated process liquid, which often is clean water. Static mixer 64 in the development tank increases the rate of floc development and increases the efficiency of the polymer injection system 66. Liquid from the development tank can be pumped or gravity fed to a secondary separation system 69 such as a clarifier, filter press, filter, or the like.

Two systems clean the reaction chamber when it is inactive. One system 70 purges the chamber and then cleans it by pumping in acid or caustic solution that removes any build-up of contaminants on the electrode plates. A second system 72 purges the chamber with water to remove contaminants. The chamber is allowed to remain filled with clean water when it is idle. The water prevents oxidation on the electrodes.

The following example provides a detailed description of a preferred embodiment of the reaction chamber.

EXAMPLE

With reference to Fig. 2, a square electrode plate 100 has equal sides twelve inches (30.5 cm) in length. An electrical connection lug 60 extends from one of the sides at a position near one of the corners. The plate can be configured as either a group one or group two plate, according to the number and position of apertures formed in it. A central

aperture 40 is formed through each group one plate. Four corner apertures 42 are formed through each group two plate. The corner apertures are spaced from the edge of the plate by 0.53 inches. Each aperture 40,42 is three-quarters inch (19 mm) in radius. With an electrode plate eighteen inches per side, the preferred aperture radius is one inch. In an electrode plate twenty-four inches per side, the preferred aperture radius is one and one-half inches.

With reference to Fig. 3, a gasket 48 has a square outer edge twelve inches per side and is sized to fit over the electrode plate with edges aligned. The inside edge of the gasket is contoured in an undulating pattern. At a position over the corner aperture of the electrode, the gasket is shaped with a trough or recess 102 having a concave curve on a three-fourths inch radius. The concave curve is located on the gasket to align with the edge of a corner aperture 42 of a group two plate over approximately the outermost one-half of the circular aperture. In a gasket having eighteen inch side edges, the concave curve has a one inch radius; or with a gasket having twenty-four inch side edges, the curve has a one and one-half inch radius, or in each case conforming to the radius of the aperture in a mating electrode plate.

The inner edge of the gasket forms a crest or convex curve 104 between concave curves 102. The apex or center point of the crest is spaced two inches from the outer edge of the gasket. The end of the crest meeting the trough blends smoothly. In a gasket having eighteen inch side edges, the apex of the crest is three inches from the outer edge; or with a gasket having twenty-four inch side edges, the apex of the crest is four inches from the outer edge. Gaskets typically will be one-eighth inch in thickness.

Spacers 46 are shaped identically to gaskets 48 but vary in thickness. Suitable spacer thicknesses are one-quarter, three-eighths, one-half, three-fourths, and one inch.

With reference to Fig. 4, the reaction chamber 12 is formed by a stack of electrode plates arranged between top and bottom pressure plates 52. Each electrode has a gasket on both its top and bottom face, and a spacer 46 is interposed between the gaskets associated with juxtaposed electrodes. In addition, an end gasket 48 and an end spacer 46 are interposed between each of the pressure plates and each end electrode. Elongated compression members 56 join the pressure plates and allow them to be drawn toward each

other to compress the gaskets. With reference to Fig. 5, the assembled reaction chamber may include bolts or tightening rods 56 at each corner of the pressure plates. Alternate compression members such as cam-locking rods 58 may be located at one or more locations intermediate the corners.

With reference to Fig. 6, the electrode plates in the stack are arranged with group one and group two plates in alternating positions, with the connecting lugs in alternating directions. This eases connection of one electrical pole, such as the positive pole, to every other plate, such as all of the group one plates. The opposite pole, such as the negative pole, is connected to all group two plates. The pressure plates 52 are provided with a fitting or connecting aperture 54 for an inlet or outlet to the reaction chamber.

With reference to Fig. 7, the flow path through the reaction chamber 12 is sinuous. Liquid entering the chamber through one end is directed sequentially through alternating electrodes of groups one and two, in whatever order is selected during assembly of the chamber. The liquid follows a flow path 106 that variously diverges and converges as its traverses each treatment zone, as defined between two juxtaposed electrode plates.

With reference to Figs. 8, the flow within each zone is represented by the arrows 106. This flow is turbulent due to the varying contour of the zone. The liquid to change velocity frequently. For example, in passing through the four apertures 42 of a group two plate, the liquid sees an overall large passageway represented by the areas of the four apertures. The liquid can flow relatively slowly through such a large portal. However, when subsequently passing through the single aperture 40 of the juxtaposed group one plate, the liquid sees a relatively small portal represented by the area of the single aperture. The liquid must flow relatively faster through the smaller portal. Additional velocity changes result as the liquid passes from the narrow portions of a single zone to a wider portion, or vice versa. This turbulent flow improves the efficiency of the electrocoagulation process and helps to clean the electrode surfaces of accumulated precipitates or floc.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown

new material
added here

and described, and accordingly all suitable modifications and equivalents may be regarded as falling within the scope of the invention as defined by the claims that follow.

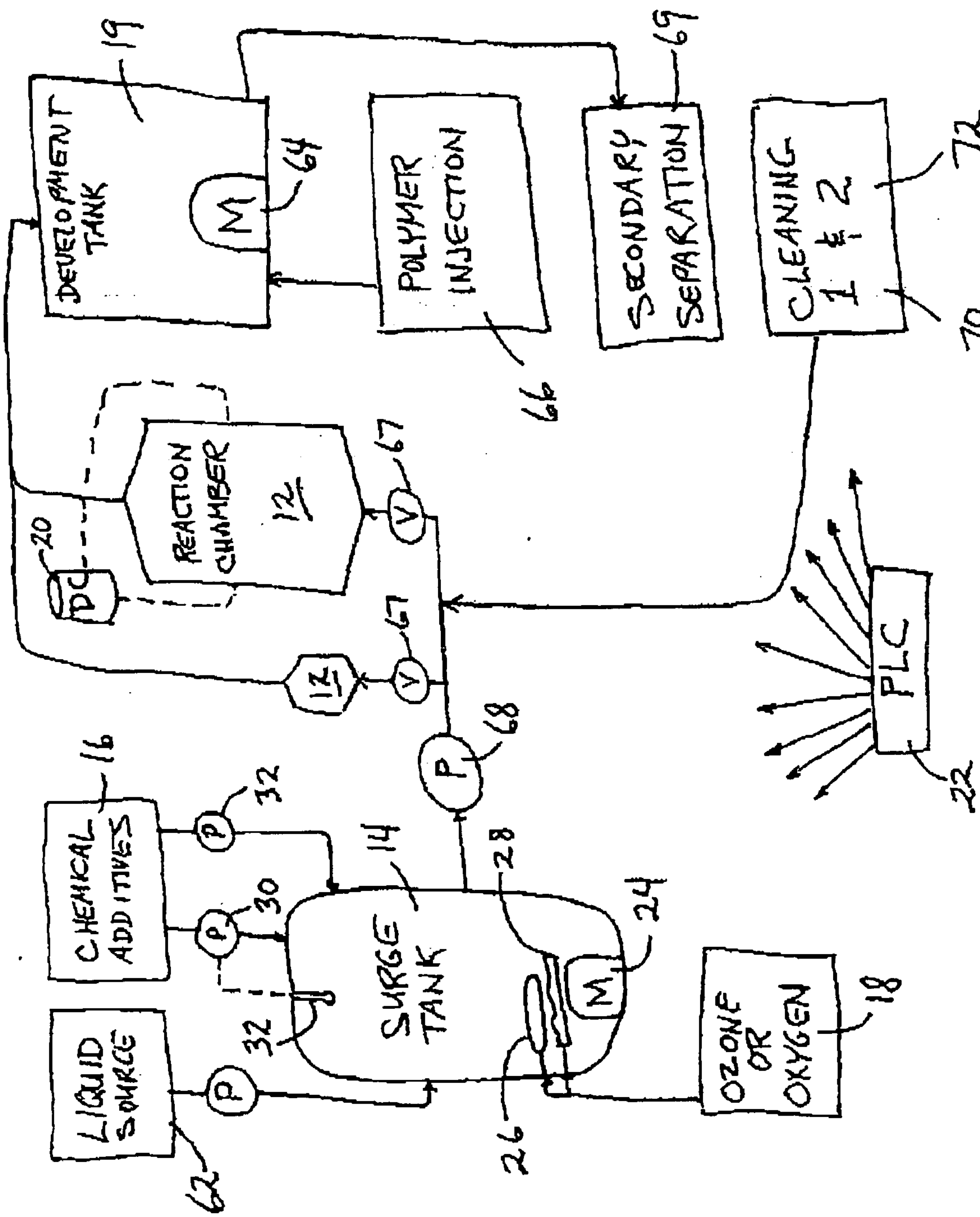

DEVELOPMENT TANK
19
M
64
POLYMER INJECTION
66
SECONDARY SEPARATION
69
CLEANING 1 & 2
70
72
REACTION CHAMBER
12
DC
20
V
67
12
PLC
22
CHEMICAL ADDITIVES
16
P
32
30
14
28
SURGE TANK
24
LIQUID SOURCE
62
26
OZONE OR OXYGEN
18
68

FIG. 1

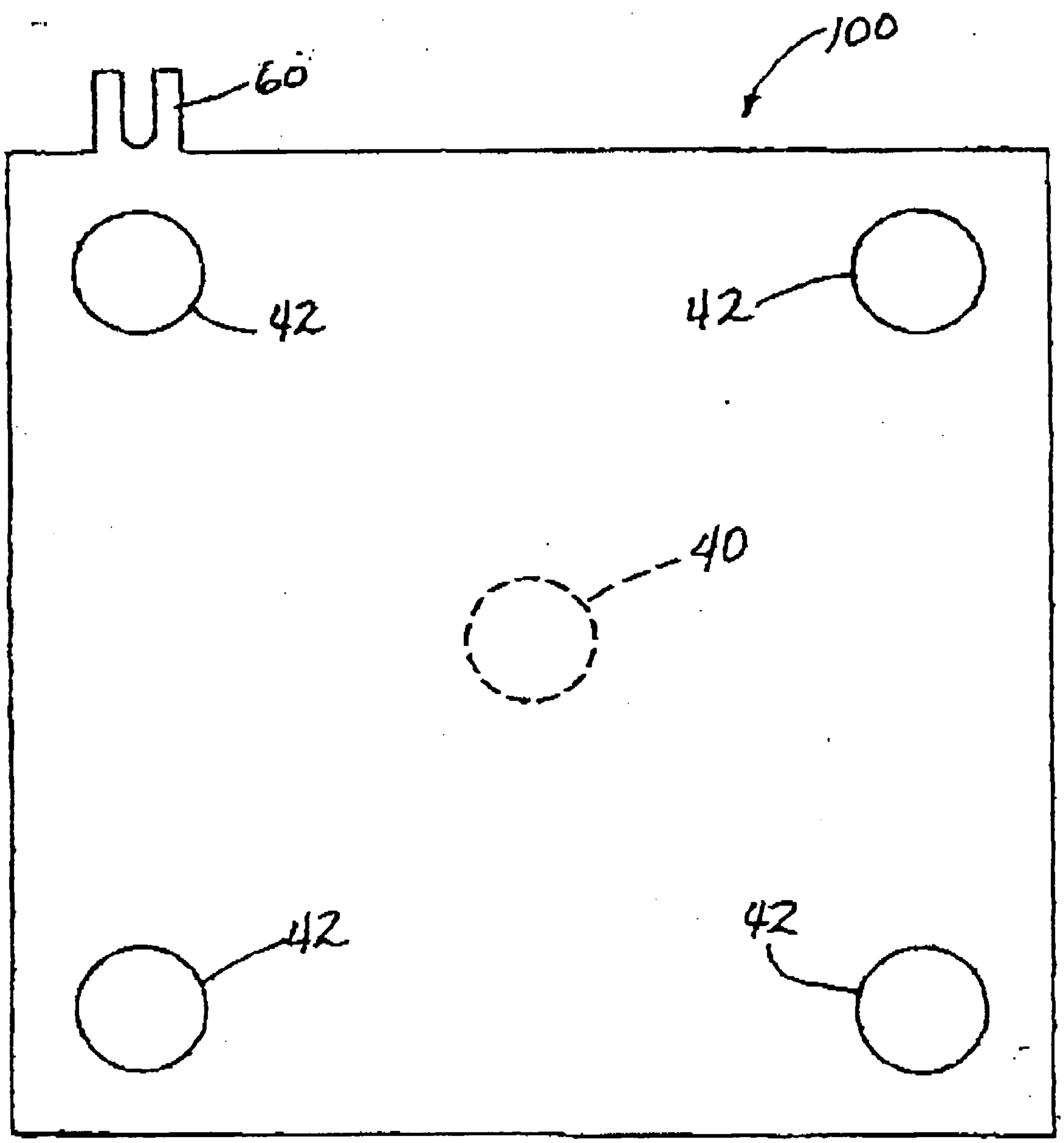


FIG. 2

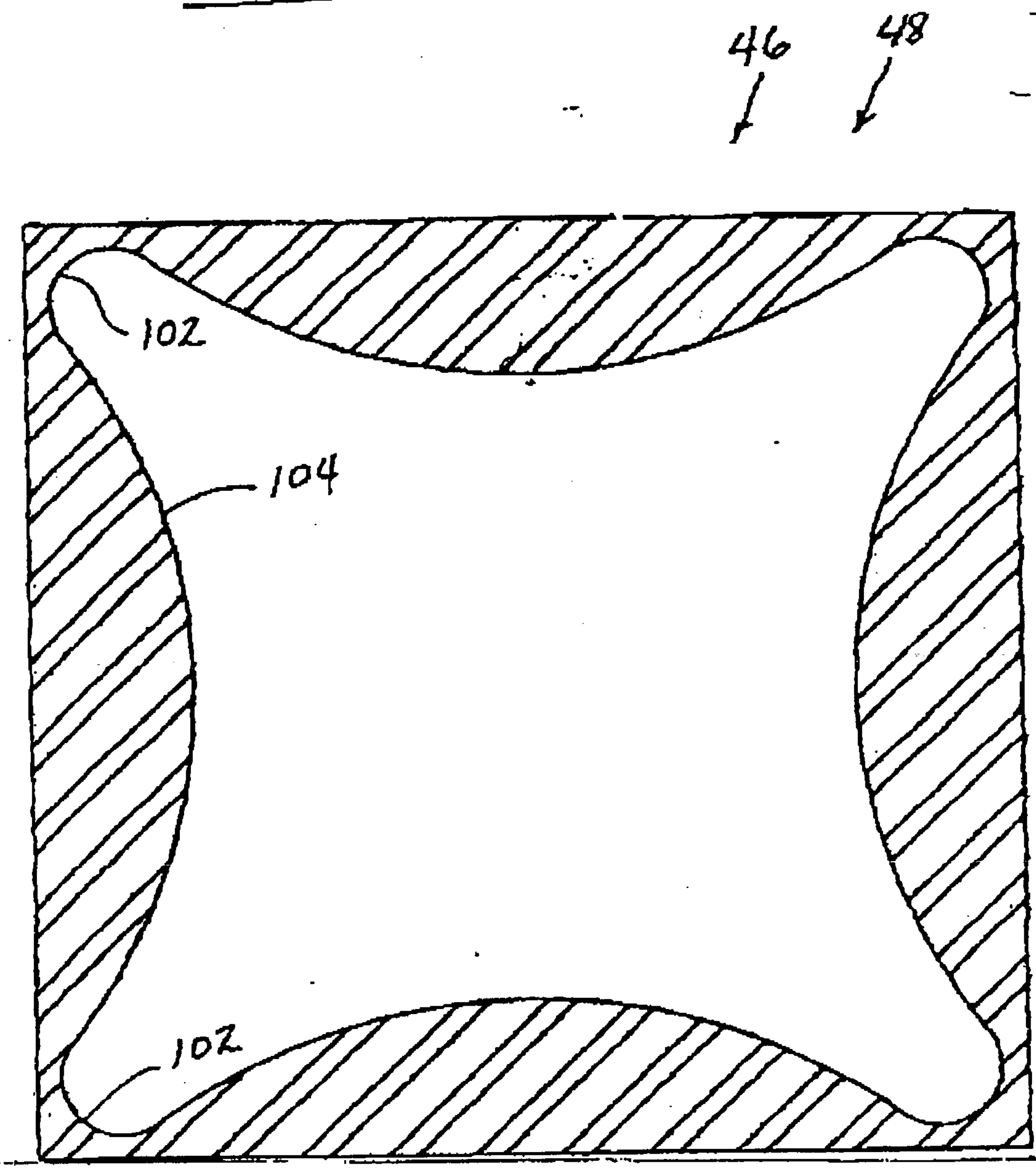


FIG. 3

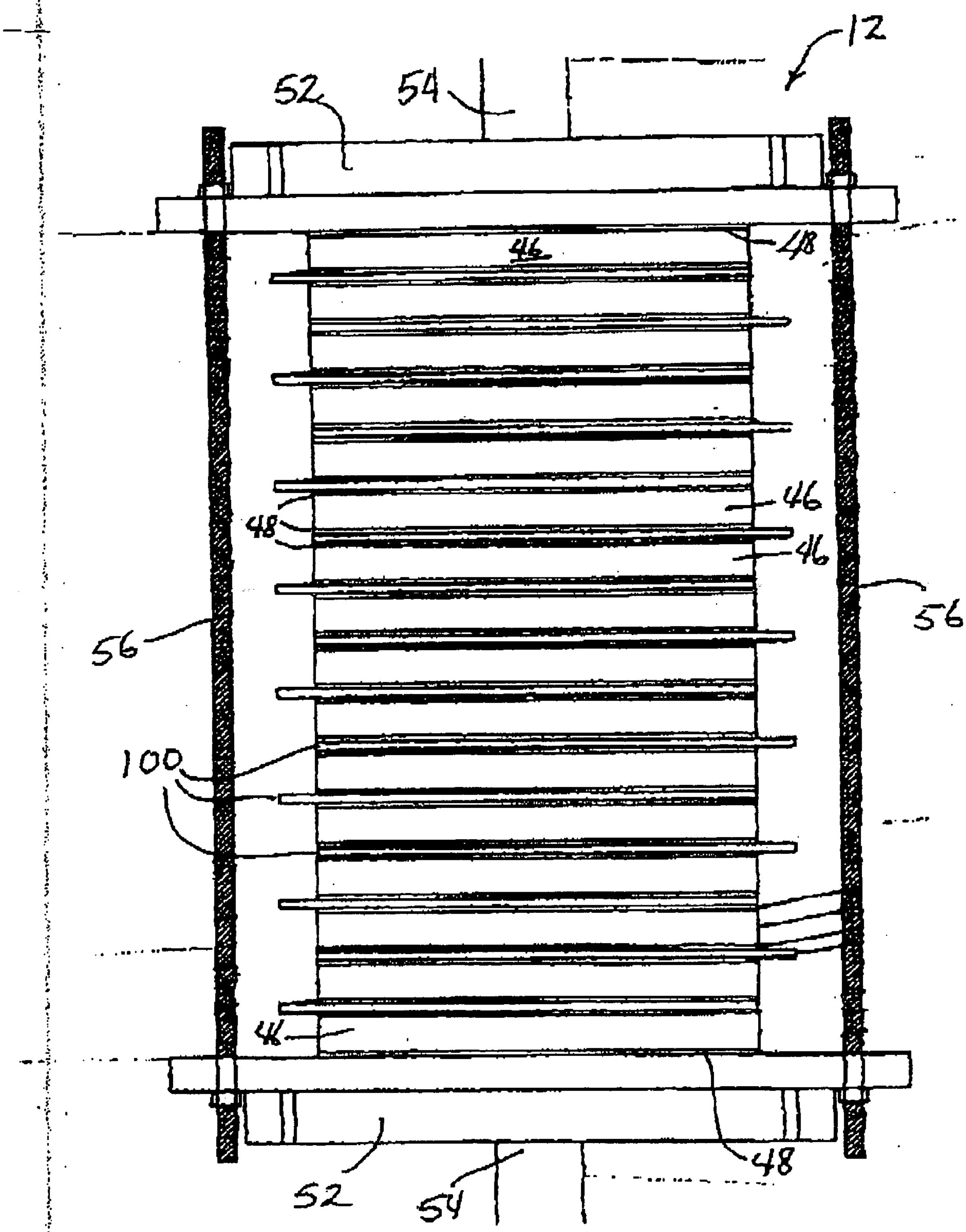


FIG. 4

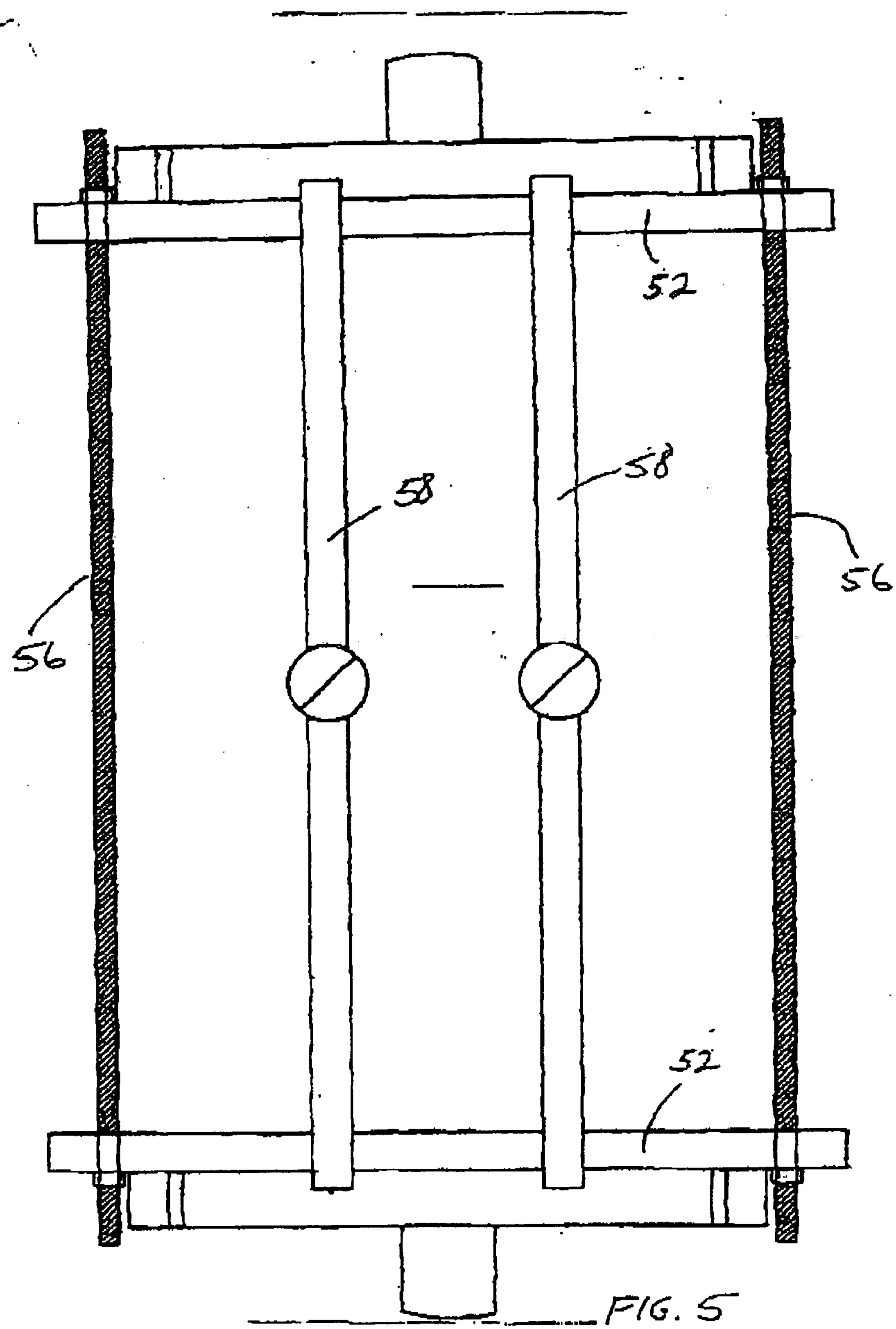


FIG. 5

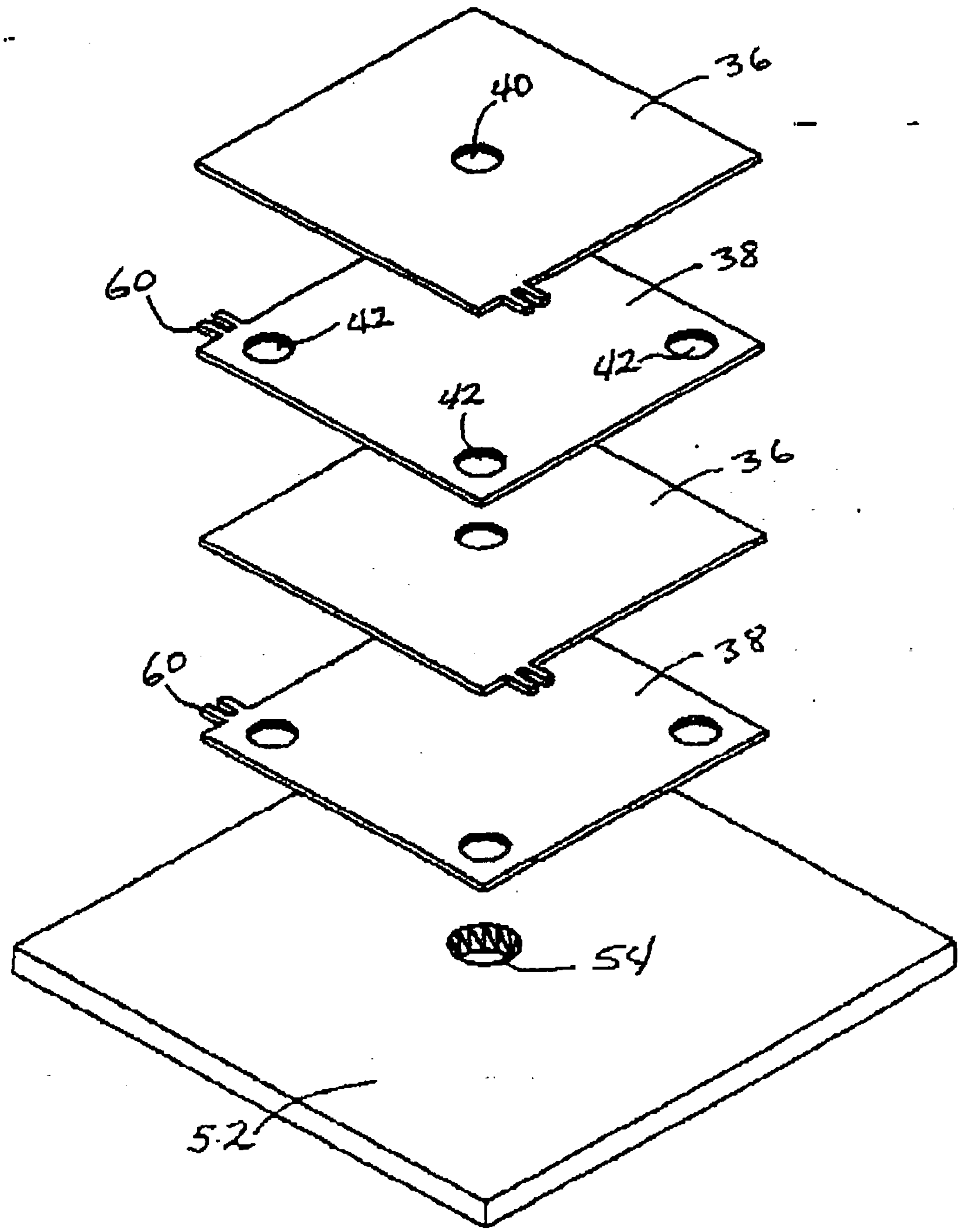


FIG. 6

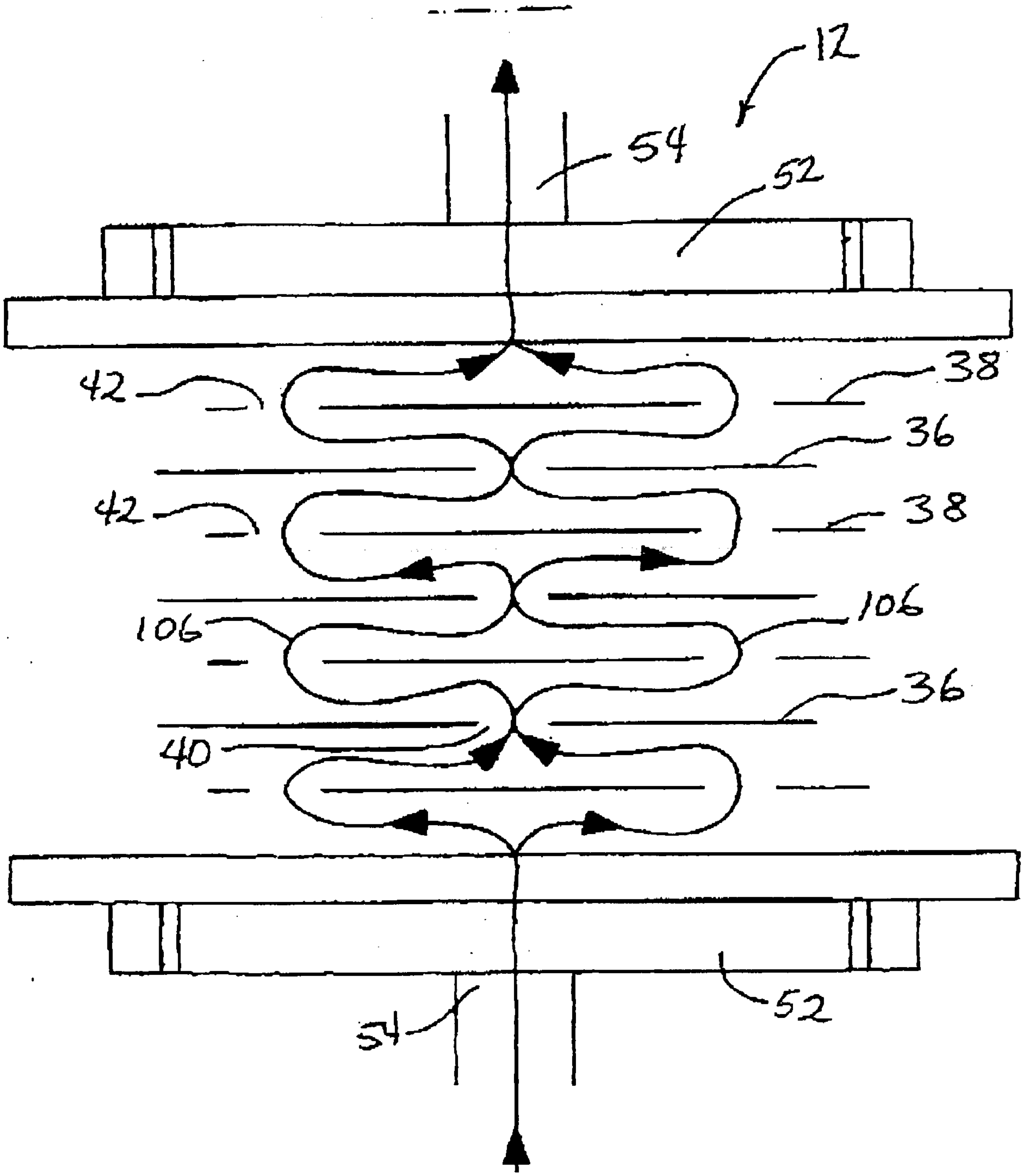


FIG. 7

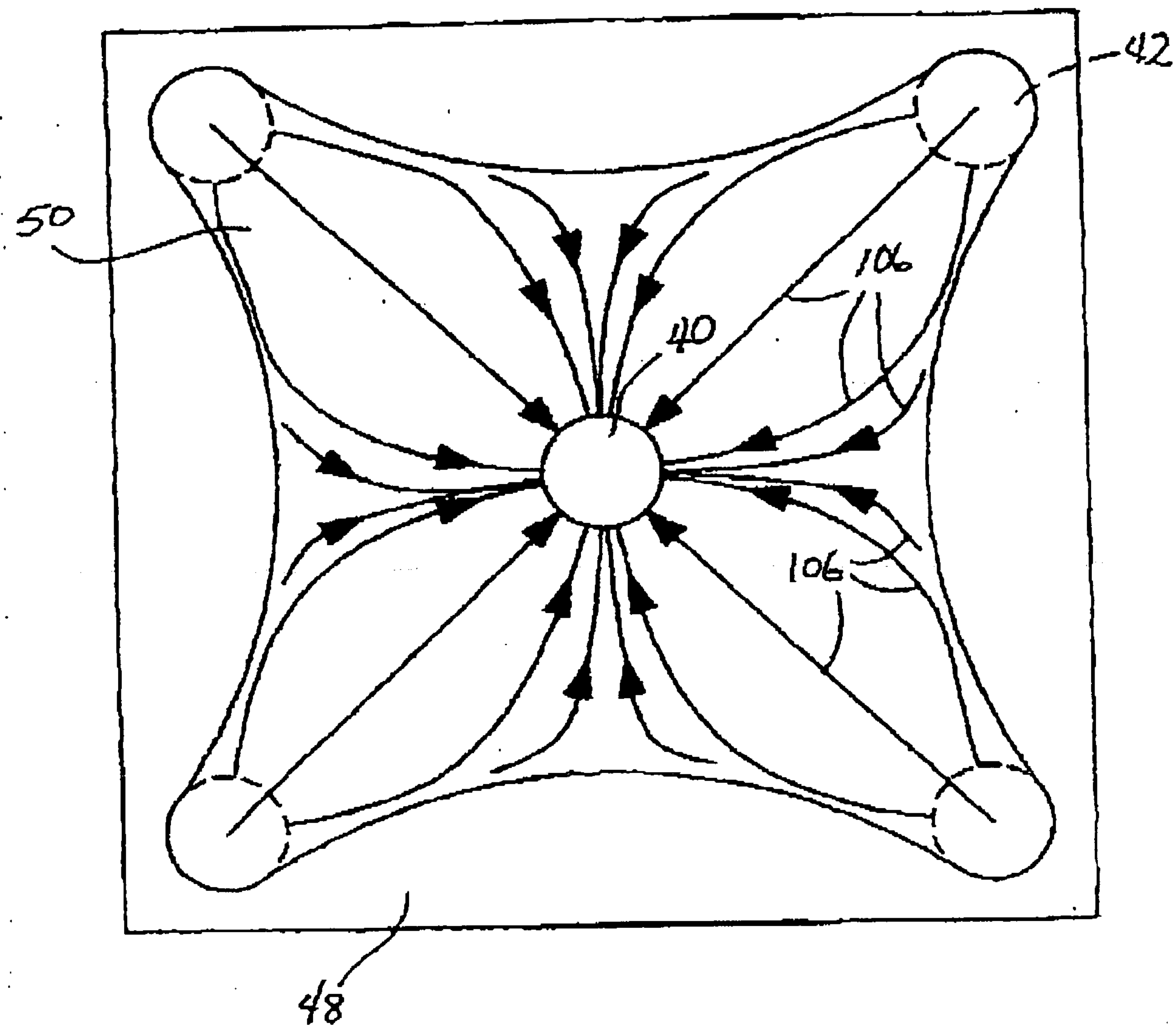


FIG 8

Exhibit B

ATTachment 4

utility filing

TRANSMITTAL LETTER TO THE UNITED STATES RECEIVING OFFICE

Date	10 October 2002
International Application No.	
Attorney Docket No.	GIL 1012

I. Certification under 37 CFR 1.10 (if applicable)

EO900209685US
Express Mail mailing number

10 October 2002
Date of Deposit

I hereby certify that the application/correspondence attached hereto is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Assistant Commissioner for Patents, Washington, D.C. 20231.

Signature of person mailing correspondence

Kyle W. Rost
Typed or printed name of person mailing correspondence

II. ☑ New International Application

TITLE: ELECTROCOAGULATION REACTION CHAMBER AND METHOD

Earliest priority date (Day/Month/Year): 12/10/2001

SCREENING DISCLOSURE INFORMATION: In order to assist in screening the accompanying international application for purposes of determining whether a license for foreign transmittal should and could be granted and for other purposes, the following information is supplied. (Note: check as many boxes as apply):

A. ☐ The invention disclosed was not made in the United States.

B. ☐ There is no prior U.S. application relating to this invention.

C. ☑ The following prior U.S. application(s) contain subject matter which is related to the invention disclosed in the attached international application. (NOTE: priority to these applications may or may not be claimed on form PCT/RO/101 (Request) and this listing does not constitute a claim for priority.)

application no.	60/329289	filed on	12 October 2001
application no.		filed on	

D. ☑ The present international application contains additional subject matter not found in the prior U.S. application(s) identified in paragraph C. above. The additional subject matter is found on pages 16-26 and ☑ DOES NOT ALTER ☐ MIGHT BE CONSIDERED TO ALTER the general nature of the invention in a manner which would require the U.S. application to have been made available for inspection by the appropriate defense agencies under 35 U.S.C. 181 and 37 CFR 5.1. See 37 CFR 5.15

III. ☐ A Response to an Invitation from the RO/US. The following document(s) is(are) enclosed:

A. ☐ A Request for An Extension of Time to File a Response

B. ☐ A Power of Attorney (General or Regular)

C. ☐ Replacement pages:

pages		of the request (PCT/RO/101)	pages		of the figures
pages		of the description	pages		of the abstract
pages		of the claims			

D. ☐ Submission of Priority Documents

Priority document		Priority document	

E. ☐ Fees as specified on attached Fee Calculation sheet form PCT/RO/101 annex

IV. ☐ A Request for Rectification under PCT 91 ☐ A Petition ☐ A Sequence Listing Diskette

V. ☐ Other (please specify):

The person signing this form is the:	
☐ Applicant	Kyle W. Rost, Reg. No. 27943
☑ Attorney/Agent (Reg. No.) 27943	Typed name of signer
☐ Common Representative	Signature

PTO-1382 (Rev. 08-1997)

U.S. Department of Commerce: Patent and Trademark Office

PTO/SB/05 (03-01)
Approved for use through 10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	GIL 1012
First Inventor	GILMORE, F. William
Title	ELECTROCOAGULATION REACTION CHAMBER AND METHOD
Express Mail Label No.	EO900209884US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [x] Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [x] Applicant claims small entity status. See 37 CFR 1.27.
3. [x] Specification [Total Pages 26] (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [x] Drawing(s) (35 U.S.C. 113) [Total Sheets 11]
5. Oath or Declaration [Total Pages 2]
   a. [x] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) (for continuation/divisional with Box 18 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
11. [ ] English Translation Document (if applicable)
12. [x] Information Disclosure Statement (IDS)/PTO-1449 [x] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [x] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
15. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: ____________

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: ______ / ______

Prior application information: Examiner: ____________ Group Art Unit: ______

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[x] Customer Number or Bar Code Label [redacted] or [ ] Correspondence address below

Name	26092 PATENT TRADEMARK OFFICE				
Address					
City		State		Zip Code	
Country		Telephone		Fax	

Name (Print/Type)	Kyle W. Rost	Registration No. (Attorney/Agent)	27943
Signature		Date	10/10/2002

TITLE OF INVENTION: ELECTROCOAGULATION REACTION CHAMBER AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS: Applicant claims the benefit of U.S. Provisional Patent Application Serial No. 60/329259 filed October 12, 2001.

TECHNICAL FIELD

The invention generally relates elements used in electrical and wave energy chemistry. More specifically, the invention relates to electrolytic apparatus composed of electrodes with an electrode supporting means consisting of a dielectric gasket or spacer. In a further aspect, the invention relates to an electrolytic apparatus and method that employ parallel plate electrodes to form plural separate treatment chambers or zones, with a feeding or withdrawing means providing a flow of liquid to be treated to the cells.

BACKGROUND ART

The practice of electrolysis upon aqueous solution results in production of water and an agglomerate. The latter can be separated from the water to produce a clean water. This process and its chemistry are well known, and many types of apparatus are used in the practice of it.

A primary problem in using an electrolytic process to produce clean water is a generally high cost of treatment. The direct cost of electricity is a significant part of the overall cost. The amount of electricity used in electrolytic processing is variable according to many factors in the design of an electrolytic reaction chamber. Design features that reduce electrical consumption are beneficial.

The cost of maintaining electrodes is another part of overall cost. Electrodes are consumed by the electrolytic reaction, but their consumption is basic to the chemistry of the reaction and is expected to occur over a predetermined time that is a function of reaction conditions. However, electrodes also can be fouled or short-circuited by deposit of reaction products. A fouled electrode becomes prematurely inefficient and can add to the amount of electricity consumed. Also, it will wear unevenly and will require premature replacement or removal for cleaning, either of

which adds to maintenance cost and down-time for the reaction chamber. A reaction chamber that keeps its electrodes clean during electrolytic processing is beneficial.

A reaction chamber is designed to accommodate many aspects of the electrolytic process. Primarily, the chamber must be effective and efficient in its performance. Thus, such aspects as electrode composition, spacing, and surface area are considered. Sustainable spacing between electrodes is important, so that adjacent electrodes do not contact each other and thereby produce a short circuit. The flow path through the electrodes is a significant factor, as the length of the path influences the speed with which the reaction must be performed and, thus, influences the electrical requirements of the chamber. Ease of replacing electrodes is significant, both in terms of maintenance cost and the down-time of a reaction chamber. These are only a few of the considerations that influence design of reaction chamber, which is a complex process.

One desirable configuration for a reaction chambers is known as the "filter press" design. Electrode plates are interleaved with dielectric spacers and gaskets to form an electrode stack. The stack is capped at its opposite ends by end plates, which are clamped together by suitable bolts or the like. The bolts are tightened to clamp the end plates, in turn squeezing together the elements in the stack of electrodes, gaskets and spacers. The filter press design is desirable because the stack of electrode plates is a unit that is easy to handle. Further, the spacing between plates is well controlled. The end plates can be configured for connection to inlet and outlet conduits for feeding and removing a process liquid, and the electrode plates can be suitably apertured or otherwise configured to define a flow path between the electrodes in the stack. A filter press design lends itself to the use of electrode plates having a square or rectangular shape, which is easily fabricated and, therefore, relatively low in cost.

United States Patent No. 1,541,947 to Hartman et al (1922) shows an early attempt at constructing such a filter press style reaction chamber. The electrodes are rectangular plates. Alternate plates are apertured near opposite narrower ends of the rectangle. Notably, two apertures are used at the perforated end of each rectangle. These apertures are transversely oblong, such that a considerable percentage of the perforated end is open for liquid flow from one processing chamber or zone to the

next. Thus, the stack of electrodes defines a sinuous, longitudinal flow path from edge-to-edge of the rectangle, with the direction of flow reversing in each successive zone as the process liquid flows through the series of processing zones.

Later advances in chamber design reveal that edge-to-edge sinuous flow across a rectangle is not uniform. Fluid in certain areas between the electrodes will be stagnant, allowing precipitates to foul nearby surfaces of the electrodes. United States Patent No. 4,124,480 to Stevenson discloses this problem in a filter-press design that employs edge-to-edge flow over rectangular plates in a stack. The electrode plates are slotted across the full width of alternating narrow ends to encourage the process liquid to flow over the full width of each electrode plate. However, even passing through a full width slot, the liquid stagnates along the edges of the plates, perhaps because of resistance induced by contact with the gasket or spacer located at such edges. Thus, it appears likely that longitudinal flow over a rectangular plate bounded by a side wall will be non-uniform and will result in fouling of certain areas of the plates.

The Stevenson patent also proposes a filter-press design using an alternate flow pattern with square electrode plates forming square treatment chambers. A first group of electrode plates are apertured at their center. A second group of electrode plates are relatively smaller in size than the first, such that they leave an almost continuous peripheral gap between each of the second group plates and the stack gaskets. In the second group, only the corners of the periphery are engaged between the gaskets and secure the second plates in the stack. The plates of the two groups are arranged in the stack in alternating sequence. The resulting flow path is from the center of a plate in the first group to the periphery of a plate in the second group, and vice versa.

However, it can be readily seen that such center-to-periphery and periphery-to-center flow will be non-uniform when square treatment chambers are used. In a stack of square plates, the shortest flow path, and likely the one with least resistance, is between the center hole of one plate and the midpoint along any of the four edges of a juxtaposed plate. Fouling is likely along the relatively longer flow paths near the corners of all plates in the stack, with resulting uneven wear, poorly predictable process control, higher electricity usage, short circuits, and premature plate replacement or maintenance.

It is evident that circular plates would be no more successful in producing equal length radial flow paths. Fabricating and assembling a stack of circular plates is likely to be more expensive and will not solve the problems of premature fouling. Like square plates, circular plates must be configured with portions that engage the stack gaskets; and they must provide apertures or peripheral gaps that establish a sinuous flow path between plates. A circular shape is little better than a square one in meeting these two requirements. Uneven flow paths or stagnant areas are inevitable results. Circular plates are likely to behave similarly to square plates in suffering prematurely fouled areas.

It would be desirable to overcome the existing fouling problems in reaction chambers of the filter-press design. In particular, it would be desirable to have a chamber design producing predictable wear patterns in which fouling is not a substantial issue. Such a design would enable the reaction chamber to be operated with sustained process efficiency over a predictable interval. Such a predictable interval can be determined by calculating the consumption of the electrodes according to the reaction parameters imposed upon the chamber, rather than by the unpredictable time between loss of efficiency due to fouling. Maintenance or replacement operations can be performed at scheduled intervals, allowing a high degree of confidence that the electrocoagulation process will remain effective and efficient between such service.

Further, it would be desirable to construct an electrocoagulation chamber in such a way that assembly and disassembly required very little time or technical skill. Thus, a chamber should allow streamlined insertion and removal of electrode plates or blades, as well as of spacers.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as embodied and broadly described herein, the electrocoagulation chamber and method of this invention may comprise the following.

DISCLOSURE OF INVENTION

Against the described background, it is therefore a general object of the invention to provide an improved structure for an electrocoagulation chamber, allowing rapid and simple assembly or disassembly, such as for maintenance.

Additional objects, advantages and novel features of the invention shall be set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by the practice of the invention.

According to the invention, an electrocoagulation reaction chamber is constructed of a supporting frame providing a pair of laterally spaced, longitudinally extending, dielectric rails for supporting an electrode stack. The supporting frame carries first and second end plates. An electrode stack is located intermediate the end plates. The components of the stack include a dielectric spacer that is supported on the rails and provides a central spacer opening. The stack also includes first and second electrode plates that are supported on the rails. The first electrode plate is positioned between the first end plate and the spacer, and said second electrode plate is positioned between the second end plate and the spacer. One of the electrode plates has a central electrode aperture, while the other electrode plate has one or more peripheral apertures. Both of the electrode apertures are smaller in size than the opening in the spacer. A compression device selectively applies or releases a compressive force on the end plates for compressing or releasing the electrode stack. An inlet supplies process liquid into one end of the electrode stack, while an outlet discharges the process liquid from the opposite end of the electrode stack.

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate preferred embodiments of the present invention, and together with the description, serve to explain the principles of the invention. In the drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of the overall electrocoagulation process.

Figure 2 is top plan view of a single electrode plate, showing the corner apertures in solid border, and showing an alternative central aperture in dashes.

Figure 3 is a top plan view of a single gasket or spacer.

Figure 4 is a side elevational view of an entire reaction chamber.

Figure 5 is a side elevational view of top and bottom pressure plates of a reaction chamber, showing compression members joining the pressure plates.

Figure 6 is a simplified exploded view of a portion of a reaction chamber, showing the alternating placement of electrode plates.

Figure 7 is a schematic view of the liquid flow path through a reaction chamber.

Figure 8 is a schematic view of the liquid flow path through a single treatment chamber or zone within a reaction chamber, showing the four corner apertures in one of the bordering electrode plates in dashed outline and showing the central aperture of a second bordering electrode plate in solid outline.

Figure 9 is a schematic side view of a modified embodiment of a reaction chamber.

Figure 10 is a schematic top view of the reaction chamber of Fig. 9.

Figure 11 is a side elevational view of an end plate, showing an external side.

Figure 12 is a side elevational view of a spacer resting on dielectric rails.

Figure 13 is a side elevational view of an electrode plate with peripheral apertures, resting on dielectric rails, and showing the position of a juxtaposed O-ring seal in the electrode stack.

Figure 14 is a side elevational view of an electrode plate with a single central aperture, resting on dielectric rails, and showing the relative position of a juxtaposed O-ring seal in the electrode stack.

BEST MODE FOR CARRYING OUT THE INVENTION

The invention provides a non-fouling, self-cleaning, sinuous flow, electrolytic reaction chamber that is easily assembled, disassembled, and maintained. A reaction chamber having a filter press structure is suitable for establishing and maintaining a stack of electrode plates that define a plurality of sequential treatment chambers or processing zones. The filter press style of reaction chamber is suited use in a system for treating water or other process fluids by electrocoagulation. The non-fouling characteristic of the reaction chamber is achieved by creating streamlined flow paths that confine the process liquid to a highly predictable or known flow path through each zone. Thus, in a streamlined flow path, the available surface area of the electrodes is limited to the shape of a predictable or known flow path characterized by a lack of stagnant areas.

The surface areas of the electrode can be conformed to the predictable or known flow path by several methods. First and preferred, the electrode plate is supplied in a size exceeding the size of the known or predictable flow path, and those portions exceeding the flow path are blocked. For example, the electrode plate may be generally square, which is not a desirable shape for a flow path and, therefore, contains surplus area.

The portions of the plate not a part of the predictable or known flow path are blocked from contact with the process liquid. Such blocking may be accomplished by supplying a gasket cut into a configuration that lies over the portion of the plate to be blocked. If a spacer is used in combination with a gasket between juxtaposed plates, the spacer may be cut in the same shape as the gasket so that it will support the gasket against the plate. When a stack of electrode plates, gaskets and spacers are compressed in a filter press style reaction chamber, the gaskets are snugly compressed against the plates, forming a liquid tight seal. The remaining, unblocked surface areas of the electrodes are in contact with the process fluid. Because the unblocked areas bound a known or predicted flow path, the unblocked areas are self-cleaned by the liquid flow.

A second method of conforming the surface area of the electrode to the predictable or known flow path is by providing the electrode plates in the size and configuration of the flow path. For example, a flow path over a plate with apertures located in certain predetermined areas will define a predetermined shape. The electrode plates in a reaction chamber employing such a flow path can be cut in a matching size and predetermined shape, with supporting tabs or an additional edge portion at the periphery, as required to be engaged by gaskets. The gaskets and spacers are shaped to engage only the additional edge portions or supporting tabs of the specially shaped plates.

Empirical testing can determine the shape of flow paths in a reaction chamber. Initially, a reaction chamber employing electrode plates of a standard shape, such as a square, can be operated for a sufficient time to determine where fouling occurs. Such testing should be conducted with plates configured to define apertures in preselected locations and of size and spacing suited for process conditions. The flow paths appear on the plates as clean areas, while areas prone to stagnation or low flow

rates will be coated with deposits. The results of empirical testing establish the known or predictable flow paths for the reaction chamber. Thereafter, the gaskets and spacers can be shaped to block the plate areas not lying along the empirically determined flow path.

The invention provides a reaction chamber employing a flow path having a pattern causing the process fluid to clean the exposed electrode surfaces. The reaction chamber is of filter press construction, in which electrodes are arranged in a stack. As assembled in the stack, each electrode has a native geometric shape or outer edge contour that can be chosen for any desired characteristic, such as a physical shape suited to form a leak-proof stack, a shape that is convenient to fabricate and handle, or a shape that otherwise meets a requirement of a particular situation. Plates of regular symmetrical geometric shape relative to a center point tend to be good choices for sealing in a filter press chamber, easy handling, economy of manufacture and shipping, efficiency in utilization, and for forming predictable, regular flow paths. By way of example, such shapes include an equilateral triangle, square, circle, or other regular geometric shape. Elongated variations of these shapes, such as an ellipse, oval, rectangle, or an irregular shape are less desirable but are useable because the flow path ultimately will be determined by other factors, such as the relative positioning of apertures in juxtaposed plates.

A gasket separates each electrode from a juxtaposed electrode in the stack. Each gasket can be shaped at its outer edge to match the outer contour of the electrode plate. Optionally, each pair of juxtaposed electrodes are separated by two or more gaskets, and a spacer of predetermined thickness is interposed between two of the gaskets. The gaskets and spacers are planar and are of similar or substantially the same shape, such as if cut from sheet stock by the same cutting die. The gaskets lie generally over the peripheral margin of each electrode plate and have an open center area, which defines the uncovered central areas of each juxtaposed pair of electrodes. The uncovered area of the electrodes is the active area that contacts process liquid and participates in an electrolytic reaction with the process liquid. The uncovered area between each pair of electrodes constitutes a separate treatment chamber or zone.

A means for establishing an electrical connection to each electrode plate allows each plate to carry a polar charge. For example, an electrically conductive ear may extend from one or more edges of each square plate to beyond the outer edge of the gasket, providing a connection point for an electrical source. Adjacent plates may be oppositely charged by a direct current (DC) electrical source, with the result that each treatment chamber or zone is defined by one positively charged plate and one negatively charged plate.

The electrodes define apertures allowing process liquid to pass from one zone to the next in the stack of electrodes. Each end of the electrode stack is capped by an end plate or pressure plate. The opposite pressure plates are joined together by elongated bolts, threaded rods, or other means for drawing the pressure plates toward each other. The pressure plates compress the electrode stack, primarily by compressing the gaskets to form a leak proof seal against the plates and spacers. The stack of electrode plates, gaskets, spacers and joined pressure plates together defines a reaction chamber. The pressure plates provide inlet and outlet fittings for transmitting process liquid through the reaction chamber. The apertures in the plates provide a flow passage for the process fluid to follow through the reaction chamber.

The apertures through the electrode plates establish a flow path passing sequentially through each of the treatment chambers or zones established between juxtaposed plates in the electrode stack. The flow pattern between sequential apertures is determined by the aperture positions and the configuration of the active or exposed electrode surfaces.

The plates in the stack consist of at least two groups, in which each group is configured with a different aperture pattern from the other group. The plates of the first group, or group one, each define a central and preferably circular aperture, located near the geometric center of the electrode plate. The plates of the second group, or group two, each define a plurality of peripheral apertures, preferably circular or arcuate in shape.

In a plate shaped with corners or distal points, such as a square or triangular plate, an efficient usage of electrode plate area suggests locating one of these peripheral apertures near each of the corners or points of the electrode plate. Thus,

in a square electrode plate, four peripheral apertures are used with one in or near each corner of the square.

In a circular plate or other plate without corners or points, the peripheral apertures are located near the peripheral edge of the plate. Preferably the peripheral apertures are equidistant from each other and from the center of the plate.

Plates of the two groups are arranged in alternating sequence in the electrode stack. Each treatment chamber or zone is bounded by one plate having a central aperture and one plate having a plurality of peripheral apertures. The flow path from zone to zone passes sequentially through the alternating hole patterns. Thus, in one of the zones the direction of liquid flow is from the center aperture of a plate from group one, spreading outwardly to the multiple peripheral apertures of a next sequential plate in the stack, which is from group two.

As the fluid enters the next zone, the direction of flow reverses. The flow pattern converges inwardly toward the center of the next sequential plate in the stack, which is from group one. This flow pattern of diverging and converging shape is repeated through the stack of electrode plates. The flow pattern causes turbulent flow of the process liquid, which encourages self-cleaning of the electrodes. The reversal of directions contributes to turbulent flow, which assists in cleaning the electrode plates and improves reaction speed and efficiency.

In almost every situation, the area of the aperture in a group one plate is expected to be unequal to the sum of the areas of the plural apertures in a group two plate. Consequently, the process liquid will undergo changes in velocity as it moves from one treatment chamber to the next. These velocity changes further contribute to turbulent flow.

The configuration of the inner edges of the spacers and gaskets is designed to block stagnant areas or areas of relatively low flow rate, such that the flow rate cannot sustain a clean condition of the electrode surfaces. Empirical testing with circular peripheral apertures shows that the inner edge of the gasket should have an undulated shape, consisting of trough portions and crest portions. The inner edge of the gasket defines a recess or concave trough at each of the peripheral apertures of a group two plate. The trough or recess is centered along the outside edge of one of the peripheral

apertures. Thus, the number and positions of the troughs is equal to the number and positions of the peripheral apertures.

The contour of each trough portion tracks the outermost edge of a peripheral aperture up to about one-half the circumference of the aperture. The remaining half of an aperture's circumference is the innermost edge. This edge is open toward the center of the treatment chamber to allow process liquid to flow from the peripheral aperture of a group two plate toward the center aperture of a group one plate.

Neighboring trough portions of the undulated gasket edge are joined by a crest portion. Between troughs, the inner edge of the gasket defines a convex edge or crest centered on the central aperture of a group one plate. The apex of the convex edge typically will be spaced from the edge of the center aperture. A suitable spacing can be determined by the process of empirical testing. Often the crest will be separated from the central aperture by two or more diameters of the central aperture.

With reference to Fig. 1 of the drawings, a system 10 for treating a process liquid by electrocoagulation can employ a filter press style reaction chamber 12 using streamlined flow paths. On the upstream side of the chamber, the system can include a surge tank 14; a means for supplying chemical enhancement additives 16; and an ozone generator or oxygen source 18. On the downstream side of the chamber 12, the system can provide a development tank 19. In addition, the system is powered from a DC power supply 20 and controlled by a programmed processor such as a program logic controller (PLC) 22. In addition, the system may include supplemental standard equipment such as valves (V) and pumps (P) as required.

In a representative system, surge tank 14 holds a minimum of five minutes supply of process liquid, based on the applicable flow rate through the system. The surge tank contains a static mixer 24 for ensuring that any chemical additives 16 are thoroughly mixed with the process liquid. An ozone diffuser 26 or an oxygen micro-bubbler 28 are located near the bottom of the tank.

Chemical enhancement additives 16 commonly are acid or caustic solution for altering the pH of the process liquid. A metering pump 30 is controlled by a pH probe 32 in the surge tank for blending the acid or caustic chemical additives into the process liquid. Other additives can be added by a pump 34 controlled by a timer in the processor.

The ozone generator or oxygen source 18 is used to accelerate the oxidation rate of the electrolytic reaction. It also treats contaminants that may not be adequately treated in the reaction chamber. It is sized according to the flow rate of the system. Oxygen increases the overall oxidation rate of the electrolytic process. When ozone is used in place of oxygen, the rate of the overall oxidation reaction is increased by a factor of about thirteen. However, oxygen is less expensive and adequate for many applications.

With general reference to the Figs. 1-8 of the drawings, a reaction chamber 12 can be constructed of square electrode blades or plates 100 alternating between group one plates 36 and group two plates 38. The group one plates 36 have an aperture 40 at the center, while the group two plates have peripheral apertures, such as four apertures 42 distributed with one in each corner. The areas of the holes 40,42 are calculated to cause a pressure differential so that the velocity of the process liquid varies and causes turbulent flow as its passes between juxtaposed plates.

The plates are separated by spacers 46 formed of a chemically inert material such a polyvinylchloride. The spacers are selected for their predetermined thickness, which establishes a corresponding gap between the electrodes. A wide variety of spacer thickness can be preselected to accommodate the electrical requirements of the process liquid.

A gasket 48 is located between each plate and spacer for sealing the treatment chambers or zones 50 within the electrode stack. The gaskets and spacers are shaped by their inside edges to define streamlined flow paths in each treatment chamber 50. Gasket material typically is of a durometer in the range from sixty to seventy to produce a liquid tight seal without requiring adhesive. To a small degree, the gaskets influence the gap between electrodes. In addition, gaskets can be chosen with a preselected thickness to change the electrical characteristics of the reaction chamber.

The electrode stack is held in place by opposing pressure plates 52 located at opposite ends of the stack. The plates are equipped with fittings 54 for attaching inlet and outlet conduits to the chamber. The plates 52 are held together and compressed against the electrode stack by suitable compression rods that may include bolts, threaded rods, cam-locking fastener rods and the like. A set of four compression bolts 56 may connect the plates 52 at the four corners of the stack. In addition, another

compression means such as a cam-locking fastener 58 may interconnect the plates 52 at the midpoint of each straight side of the stack. The periphery of each electrode plate, gasket and spacer may be apertured to be threaded over the compression rods as an aid to the assembly of the electrode stack.

Each electrode plate 100 carries an electrically conductive ear 60 for receiving a DC electrical connection. The ears extend outside the gaskets on the outer surface of the electrode stack. A guard or cover can be placed over the reaction chamber to prevent inadvertent contact with the ears or any other electrified portion of the reaction chamber. As a safety measure, the guard may be equipped with an interlocking switch for shutting off power to the system when the guard is removed.

The development tank 19 receives treated process liquid under pressure from the reaction chamber 12. The treated liquid resides in tank 19 while floc forms. A static mixer 64 in tank 19 enhances floc development. A polymer injection system 66 can be used where polymers will improve the settling process.

The DC power supply 20 receives alternating current (AC) power from the grid and transforms it to DC through a rectifier. The positive and negative sides of the DC supply are selectively connected to electrode blades in the reaction chamber. The DC supply can switch or reverse polarity to the electrodes. Periodically reversing polarity minimizes any buildup of oxides on the electrodes.

Overall system control resides in the program logic controller 22. Controlled features include liquid flow rate, operation of pumps and valves, and application of power to the reaction chamber electrode plates.

In operation, the system 10 is suited to treat process liquids, which may include waste water, drinking water, or process water. Process liquid is pumped from a source 62 to the surge tank 14 at a specified number of gallons per minute. The surge tank provides flooded suction for a feed pump 68. It also receives chemical additives 16 such as acid or caustic solution to adjust the pH of the process liquid. The static mixer 24 blends the additives and the process liquid. Ozone or oxygen 18 are injected into the process liquid to enhance the normal rate of oxidation that will take place in the reaction chamber 12.

Optionally, polymers can be injected into the liquid in the surge tank to improve the floc structure of certain process streams. For example, when thickening

a stream of sewage sludge, five percent of the normal polymer rate improved the resulting solids from seventeen percent to over twenty percent.

The process liquid from the surge tank is pumped under pressure through a connection to one or more reaction chambers 12. Each reaction chamber contains electrode plates formed of selected metals to provide the optimum ions for the appropriate chemical treatment of the process liquid. If multiple reaction chambers 12 are connected to the surge tank, individual reaction chambers can be placed on-line or off-line by suitable valves 67. This allows adjustment for varying flow rates and permits maintenance of individual chambers while processing continues in another chamber. The power supply 20 provides DC current to the electrodes, where the electricity passes through the process liquid and causes chemical reactions tending to form impurities into precipitates and flocs.

The treated process liquid exits the reaction chamber and enters the development tank 19 while still under pressure. A residence time in the development tank allows floc to develop and be separated from the remaining portion of the treated process liquid, which often is clean water. Static mixer 64 in the development tank increases the rate of floc development and increases the efficiency of the polymer injection system 66. Liquid from the development tank can be pumped or gravity fed to a secondary separation system 69 such as a clarifier, filter press, filter, or the like.

Two systems clean the reaction chamber when it is inactive. One system 70 purges the chamber and then cleans it by pumping in acid or caustic solution that removes any build-up of contaminants on the electrode plates. A second system 72 purges the chamber with water to remove contaminants. The chamber is allowed to remain filled with clean water when it is idle. The water prevents oxidation on the electrodes.

According to one detailed embodiment of the reaction chamber, and with reference to Fig. 2, a square electrode plate 100 has equal sides 30.5 cm (12 in) in length. An electrical connection ear 60 extends from one of the sides at a position near one of the corners. The plate can be configured as either a group one or group two plate, according to the number and position of apertures formed in it. A central aperture 40 is formed through each group one plate. Four corner apertures 42 are formed through each group two plate. The corner apertures are spaced from the edge

of the plate by 13.5 mm (0.53 in). Each aperture 40,42 is 19 mm (0.75 in) in radius. With an electrode plate 45.7 cm (18 in) per side, the preferred aperture radius is 2.5 cm (1 in). In an electrode plate 61 cm (24 in) per side, the preferred aperture radius is 3.8 cm (1.5 in).

With reference to Fig. 3, a gasket 48 has a square outer edge 30.5 cm (12 in) per side and is sized to fit over the electrode plate with edges aligned. The inside edge of the gasket is contoured in an undulating pattern. At a position over the corner aperture of the electrode, the gasket is shaped with a trough or recess 102 having a concave curve on a 19 mm (0.75 in) radius. The concave curve is located on the gasket to align with the edge of a corner aperture 42 of a group two plate over approximately the outermost one-half of the circular aperture. In a gasket having 45.7 cm (18 in) side edges, the concave curve has a 2.5 cm (1 in) radius; or with a gasket having 61 cm (24 in) side edges, the curve has a 3.8 cm (1.5 in) radius, or in each case conforming to the radius of the aperture in a mating electrode plate.

The inner edge of the gasket forms a crest or convex curve 104 between concave curves 102. The apex or center point of the crest is spaced 5 cm (2 in) from the outer edge of the gasket. The end of the crest meeting the trough blends smoothly. In a gasket having 45.7 cm (18 in) side edges, the apex of the crest is 7.6 cm (3 in) from the outer edge; or with a gasket having 61 cm (24 in) side edges, the apex of the crest is 10 cm (4 in) from the outer edge. Gaskets typically will be 3.2 mm (0.125 in) in thickness.

Spacers 46 are shaped identically to gaskets 48 but vary in thickness. Suitable spacer thicknesses are 6.4 mm, 9.5 mm, 12.7 mm, 19 mm, and 25.4 mm (1.4 in, 3/8 in, 1/2 in, 3/4 in, and 1 in).

With reference to Fig. 4, the reaction chamber 12 is formed by a stack of electrode plates arranged between pressure plates 52 on opposite ends. Each electrode is juxtaposed to a gasket on each of its faces, and a spacer 46 is interposed between the gaskets associated with juxtaposed electrodes. In addition, an end gasket 48 and an end spacer 46 are interposed between each of the pressure plates and each end electrode. Elongated compression members 56 join the pressure plates and allow them to be drawn toward each other to compress the gaskets. With reference to Fig. 5, the assembled reaction chamber may include bolts or tightening rods 56 at each corner of

the pressure plates. Alternate compression members such as cam-locking rods 58 may be located at one or more locations intermediate the corners.

With reference to Fig. 6, the electrode plates in the stack are arranged with group one and group two plates in alternating positions, with the electrical connecting ears in alternating directions. This eases connection of one electrical pole, such as the positive pole, to every other plate, such as all of the group one plates. The opposite pole, such as the negative pole, is connected to all group two plates. The pressure plates 52 are provided with a fitting or connecting nipple 54 for an inlet or outlet to the reaction chamber.

With reference to Fig. 7, the flow path through the reaction chamber 12 is sinuous. Liquid entering the chamber through one end is directed sequentially through alternating electrodes of groups one and two, in whatever order is selected during assembly of the chamber. The liquid follows a flow path 106 that variously diverges and converges as its traverses each treatment zone, as defined between two juxtaposed electrode plates.

With reference to Fig. 8, the flow within each zone is represented by the arrows 106. This flow is turbulent due to the varying contour of the zone. The liquid changes velocity frequently. For example, in passing through the four apertures 42 of a group two plate, the liquid sees an overall large passageway represented by the areas of the four apertures. The liquid can flow relatively slowly through such a large portal. However, when subsequently passing through the single aperture 40 of the juxtaposed group one plate, the liquid sees a relatively small portal represented by the area of the single aperture. The liquid must flow relatively faster through the smaller portal. Additional velocity changes result as the liquid passes from the narrow portions of a single zone to a wider portion, or vice versa. This turbulent flow improves the efficiency of the electrocoagulation process and helps to clean the electrode surfaces of accumulated precipitates or floc.

~~Another preferred embodiment is shown in Figs. 9~~ and 10, in which a desirable reaction chamber 108 allows the number of blades or electrode plates in the electrode stack 109 to be varied. It also allows the electrode plates to be removed and reinstalled for cleaning or replacement in a simple and efficient manner. This chamber is constructed with a filter-press type of design using a frame 110 that

supports a pair of spaced apart, generally horizontal, longitudinal, dielectric rails 112. Typically a rail is constructed of metal and carries an electrically insulating wear strip or other dielectric covering 114 at all contact areas with an electrode plate. The rails are well suited to support easily fabricated, square electrode plates 101, 102, as shown in Figs. 13 and 14. The plates include laterally extending ears 116 that overlie the rails and support each plate on the rails by gravity. In addition, the ears 116 serve as supporting rail guides that allow the plates to be positioned by sliding on the rails. The rail guides 116 may have a recess or hooked shape opening to the bottom side for engaging a rail and sliding on the rail when pushed longitudinally.

The frame supports a pair of spaced apart pressure plates 118 that rest on rails 112 and serve as the opposing end plates for the intermediate electrode stack 109 of reaction chamber 108. A supporting ear or rail guide 116 extends from each lateral side of plates 118 in a suitable position for engaging the rails 112. One of the pressure plates 118 is a stationary end plate located at one longitudinal end of the rails 112, such as the right hand end in the view of Figs. 9 and 10. The stationary plate 118 is lodged against an end of frame 110, which supports the stationary plate against movement. A second pressure plate 118, at the left end of the reaction chamber in the view of Figs. 9 and 10, may be regarded as a moveable plate. The second plate 118 can be selectively pressed against the juxtaposed end of the electrode stack, pushing the stack against the stationary plate and, thus, sealing it. When pressure through the moveable plate is released, the electrode stack can be spread apart along the rails, and any component can be lifted from the dielectric rails, such as for maintenance or replacement.

With reference to Fig. 11, the external face of pressure plate 118 is configured to allow a central force on the plate to seal the electrode stack. A force dissipating pad 120 at the center of plate 118 provides a thickened contact area. A plurality of gussets 122 radiate from pad 120 and extend to the periphery of the plate. The plate may carry an inlet or outlet fitting 54. The pad and gusset structure prevents the plate from warping or deforming when a central pressure is applied on pad 120.

A compression means or device selectively pushes the moveable plate 118 against the electrode stack, sealing it against leakage and allowing pressurized operation. The compression device also selectively releases the pressure to allow

electrode plates 101,102 to be removed for maintenance or replacement. A preferred compression device is a fluid operated piston cylinder, operable between an extended position and a retracted position. A pneumatic or hydraulic powered cylinder 124 is suitable. The cylinder 124 acts between the left end of frame 110 and moveable plate 118 on the left side of the electrode stack in the view of Figs. 9 and 10. The hydraulic cylinder can work over a range of extension, allowing the number of electrode plates in the electrode stack to be varied. One end of the cylinder 124 may be connected to the frame 110, and the cylinder is positioned for the opposite end to contact the nearer end plate 118 when the cylinder is extended, to compress the electrode stack.

The electrode plates used in reaction chamber 108 provide turbulent flow of the process liquid, flowing through a flow path defined by alternating group one and group two plates. In this embodiment, the electrode plates include supporting rail guides 116 for carrying the electrode plates on the rails 112. Each pair of electrode plates is separated by a spacer that also includes rail guides 116. Fig. 12 shows a modified spacer 103 defining a central spacer opening, preferably with a round edge profile defining a circular opening of predetermined diameter. The spacer may carry a compressible seal at each face. Thus, both faces of the spacer 103 may define a retaining groove that carries an O-ring seal 117 juxtaposed to the edge of the central opening. The O-ring seal on each face of the spacer substitutes for a gasket 48. The spacer is formed of a dielectric material. The thickness of a spacer can be selected to establish a desired spacing between blades.

A single treatment chamber may be regarded as including a central spacer with a group one plate on one face and a group two plate on the opposite face. As shown in Fig. 14, the group one plate 101 defines a central aperture 40, preferably round, that is smaller than the central spacer opening. The diameter of aperture 40 preferably is about twenty percent or less of the diameter of the central spacer opening. Plate 101 includes lateral rail guides 116 capable of supporting the plate 101 from rails 112. The plate may include an electrical connecting ear allowing connection to an electric power source 20, although one of the rail guides 116 may be adapted to serve this additional function. Preferably, the rail guide serving as a connecting ear is provided

with an attachment point such as hole 126 suited for connection to an electrical connecting lug and wire pigtail 128.

A modified group two electrode plate 102 is used on the opposite side of the spacer. As shown in Fig. 13, the modified plate 102 has peripheral apertures 104 configured as arcs of a peripheral circular slot. The outer edge of the arcuate apertures lies closely within the diameter of the O-ring seal 126 so that the slot is radially juxtaposed to the central spacer opening. A minimal peripheral area of plate 102 is exposed to process liquid outside the position of slot 104 to abate fouling. The slot 104 is discontinuous as necessary to support the central portion of plate 102. For example, the central, disk-shaped portion may be connected to the peripheral portion of the plate at one or more connecting areas. The connections should be as narrow as practical, with the typical arc of such a connection being about fifteen degrees. Thus, if four connecting areas are used, as shown in Fig. 13, the slot 104 will extend over about three hundred degrees, and the connecting areas will extend over about sixty degrees. The electrode plate 102 includes a connecting ear or lug attachment point 126 as previously described.

The cumulative area of apertures 104 is smaller than the size of the central spacer opening but larger than size of the opening 40 in plate 101. For example, the height or radial dimension of the arcuate slot can be about 13 mm (0.5 in) relative to a diameter of about 25.4 cm (10 in) for the central spacer opening. Process liquid is maintained in turbulent flow along the flow path passing through the differently sized openings 40 and 104. The turbulence is encouraged by the non-linear flow path and by differing areas of the apertures in juxtaposed plates.

Electrical power is easily applied or removed from the plates of the reaction chamber 108. In one desirable arrangement, plates 101 may be arranged on dielectric rails 112 with the connecting points 126 all on one side of the chamber, while plates 102 are arranged with point 126 on the opposite side of the chamber. Positive connections may be applied to one side, while negative connections are applied to the other. Lugs and wire pigtails 128 may carry waterproof twist plugs, often referred to as CAM connectors, that allow rapid connection or disconnection of each plate from the DC power supply 20.

The operation of the reaction chamber in Figs. 9 and 10 is streamlined and requires a minimum of maintenance labor. The reaction chamber is assembled by setting in place a desired sequence of spacers, group one plates, and group two plates on the dielectric rails 112 between the opposite end plates 118. Typically a spacer is juxtaposed to each end plate. A series of reaction zones is established, starting at one end, by adding a plate selected from one of the two groups, followed by another spacer, followed by a plate from the other group. The connecting points 126 of the two groups of plates should be positioned in a sensible way for the planned polarity of each blade, such as respectively right and left. The sequence is repeated as desired within the available length of the rails, terminating at the spacer juxtaposed to the opposite end plate.

When the hydraulic cylinder 124 is applied to compress the electrode stack, the plates and spacers move together by sliding on the rails. The stack is self-aligning. The O-ring seals produce a pressure-tight reaction chamber, enabling the process liquid to be pumped into or out of the chamber. Electricity can be connected to the plates via the pigtails either before or after the stack is compressed. Numerous patterns of electrical connection are possible. For example, power can be applied to first and last blades, or the electrode stack can be subdivided into multiple chambers. Regardless of what connection scheme is used, an advantage of reaction chamber 108 is that all electrical wiring is external of the flow path and protected by the pressurized nature of the chamber from exposure to liquid. A protective cover is applied over the electrode stack, extending at least as low as the rail guides. The wiring harness is housed above the electrical connections of the blades so that it can remain dry even when the electrode stack is opened.

The flow of process liquid through the reaction chamber will follow the flow path established by the chosen sequence of plates and spacers. Inlet and outlet fittings 54 are provided through the end plates 118. The fitting 54 serving as the inlet may contain a mixing tube to create initial turbulence in the process liquid. This turbulence is maintained by the sinuous flow path and changing velocities required by offset positions and varying sizes of the passages through plates 101 and 102.

Opening the electrode stack for cleaning is equally streamlined. The hydraulic cylinder is withdrawn, whereupon the moveable end plate, spacers, and electrode

plates can be spread freely on the rails. A catch pan 130 can be carried on the frame 110 below the rails to catch residual liquid from the opened chamber. This pan may be connected through a valve and hose to a drain, or captured liquid may be returned to the untreated process liquid.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be regarded as falling within the scope of the invention as defined by the claims that follow.

CLAIMS

1. An electrocoagulation reaction chamber for the electrolytic treatment of a stream of process liquid, comprising:

a supporting frame providing a pair of laterally spaced, longitudinally extending, dielectric rails for supporting an electrode stack;

first and second spaced apart end plates that are carried by said supporting frame;

an electrode stack that is located between said end plates and that defines a flow path therethrough for process liquid, formed of at least:

a dielectric spacer that is supported on said rails and which defines a central spacer opening that forms a portion of the flow path;

first and second electrode plates that are supported on the rails, wherein said first electrode plate is positioned between the first end plate and said spacer, and said second electrode plate is positioned between the second end plate and the spacer; and

wherein one of said electrode plates defines a central electrode aperture that is positioned centrally relative to the central spacer opening and forms a portion of the flow path; and the other of the electrode plates defines a peripheral electrode aperture that is positioned peripherally relative to the central spacer opening and forms a portion of a flow path;

a compression means for selectively applying or releasing a compressive force on the end plates for selectively applying compression to said electrode stack or releasing compression from the electrode stack;

an inlet means for supplying process liquid into a first end of the flow path; and

an outlet means for discharging process liquid from a second end of the flow path.

2. The electrocoagulation chamber of Claim 1, further comprising a means for supporting said first end plate on said rails for sliding movement.

3. The electrocoagulation chamber of Claim 2, wherein said compression means is applied against said first end plate for sliding the first end plate on said rails and against said electrode stack.

4. The electrocoagulation chamber of Claim 1, wherein said second end plate and frame are suitably arranged such that the frame braces the second end plate against movement away from said electrode stack.

5. The electrocoagulation chamber of Claim 1, wherein said dielectric spacer is supported on said rails by a means for allowing the spacer to slide longitudinally with respect to the rails.

6. The electrocoagulation chamber of Claim 1, wherein said electrode plates are supported on said rails by a means for allowing the plates to slide longitudinally with respect to the rails.

7. The electrocoagulation chamber of Claim 1, wherein said peripheral electrode aperture is juxtaposed to an edge of said central spacer opening.

8. The electrocoagulation chamber of Claim 7, wherein said edge of the central spacer opening is concave to said peripheral electrode aperture.

9. The electrocoagulation chamber of Claim 1, wherein said peripheral electrode aperture is arcuate.

10. The electrocoagulation chamber of Claim 9, wherein said peripheral electrode aperture is radially juxtaposed to said central spacer opening.

11. The electrocoagulation chamber of Claim 9, further comprising:

a compressible seal located between said spacer and each of said first and second electrode plates for forming a pressurizable electrode stack when longitudinal compressive force is applied to said first and second end plates.

12. The electrocoagulation chamber of Claim 1, wherein said peripheral electrode aperture smaller in area than said central spacer opening.

13. The electrocoagulation chamber of Claim 1, further comprising:

an electrical connection ear extending laterally of said first electrode plate;

a waterproof, selectively connectable and disconnectable wire connector joined to said connection ear; and

a DC power source connected at one pole to said waterproof wire connector.

14. The electrocoagulation chamber of Claim 1, further comprising:

a plurality of said first electrode plates, each having an electrical connection ear extending laterally; and

a plurality of said second electrode plates, each having an electrical connection ear extending laterally;

wherein the first electrode plates are arranged with said electrical connection ears extending to a first lateral side of the electrode stack; and

the second electrode plates are arranged with the electrical connection ears extending to a second lateral side of the electrode stack.

15. The electrocoagulation chamber of Claim 1, further comprising:

a catch tray carried by said frame below the electrode stack for catching process liquid when said compression means selectively releases compressive force on the electrode stack.

16. The electrocoagulation chamber of Claim 1, wherein said compression means comprises a fluid operated piston cylinder operable between an extended position and a retracted position, connected at one end to said frame and suitably positioned to push against said first end plate when in extended position.

17. A electrocoagulation reaction chamber for the electrolytic treatment of a stream of process liquid, comprising:

a supporting frame providing a pair of laterally spaced, longitudinally extending, substantially horizontally disposed dielectric rails for supporting an electrode stack;

first and second end plates carried by said supporting frame, wherein at least one of said end plates is slidably supported on said rails;

an electrode stack intermediate said first and second end plates, defining a flow path therethrough for process liquid, including:

a dielectric spacer supported on said rails and providing a central circular opening defining a portion of a flow path for process liquid;

first and second electrode plates supported on said rails, wherein said first electrode plate is positioned between said first end plate and said spacer, and said second electrode plate is positioned between said second end plate and the spacer; and

wherein one of said first and second electrode plates defines a circular central electrode aperture forming a portion of a flow path for process liquid, positioned centrally relative to said circular spacer opening and of smaller size than the circular spacer opening; and the other of the first and second electrode plates defines a plurality of peripheral electrode apertures forming a portion of a flow path for process liquid, positioned peripherally relative to the central spacer opening, and cumulatively of smaller size than the circular spacer opening;

means selectively applying and releasing a longitudinal compressive force to said first and second end plates for selectively compressing said electrode stack and releasing compression on the electrode stack;

an inlet means for supplying the process liquid into a first longitudinal end of the flow path; and

an outlet means for removing the process liquid from an opposite longitudinal end of the flow path.

18. A method of assembling an electrocoagulation chamber, comprising:

first, providing a pair of laterally spaced, longitudinally extending, generally horizontal, dielectric rails;

second, building an electrode stack on the dielectric rails by placing a sequence of alternating electrode plates and dielectric spacers on the rails, together with a pressure resistant end plate at each end of the electrode stack, wherein said electrode plates, spacers, and at least one of the end plates rest on the rails by gravity and are longitudinally slidable thereon;

third, compressing the electrode stack to seal the junction between each electrode plate and spacer.

ABSTRACT

Dielectric rails (112) support an electrode stack (109) that is compressed between end pressure plates (118). The stack is composed of a dielectric spacer (46, 103) forming a central spacer opening, separating a pair of electrode plates (101,102) that each have a different configuration of openings. A first electrode plate (101) of the pair has a central aperture, while the second electrode plate (102) of the pair has peripheral apertures. A compression device such as a hydraulic cylinder (124) compresses the stack, sliding the plates and spacers together to form a pressure-tight reaction chamber (108). When the cylinder is released, any plate or spacer is readily removed from the stack for replacement or maintenance merely by lifting it off the rails. An electric potential can be applied to each electrode plate at a connecting ear (116), which may be a one of the rail guides (116).

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	GIL 1012
First Named Inventor	GILMORE, F. William
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Art Unit	
Examiner Name	

As the below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original and first inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ELECTROCOAGULATION REACTION CHAMBER AND METHOD

(Title of the Invention)

the specification of which

☑ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ______ as United States Application Number or PCT International

Application Number ______ and was amended on (MM/DD/YYYY) ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

DECLARATION — Utility or Design Patent Application

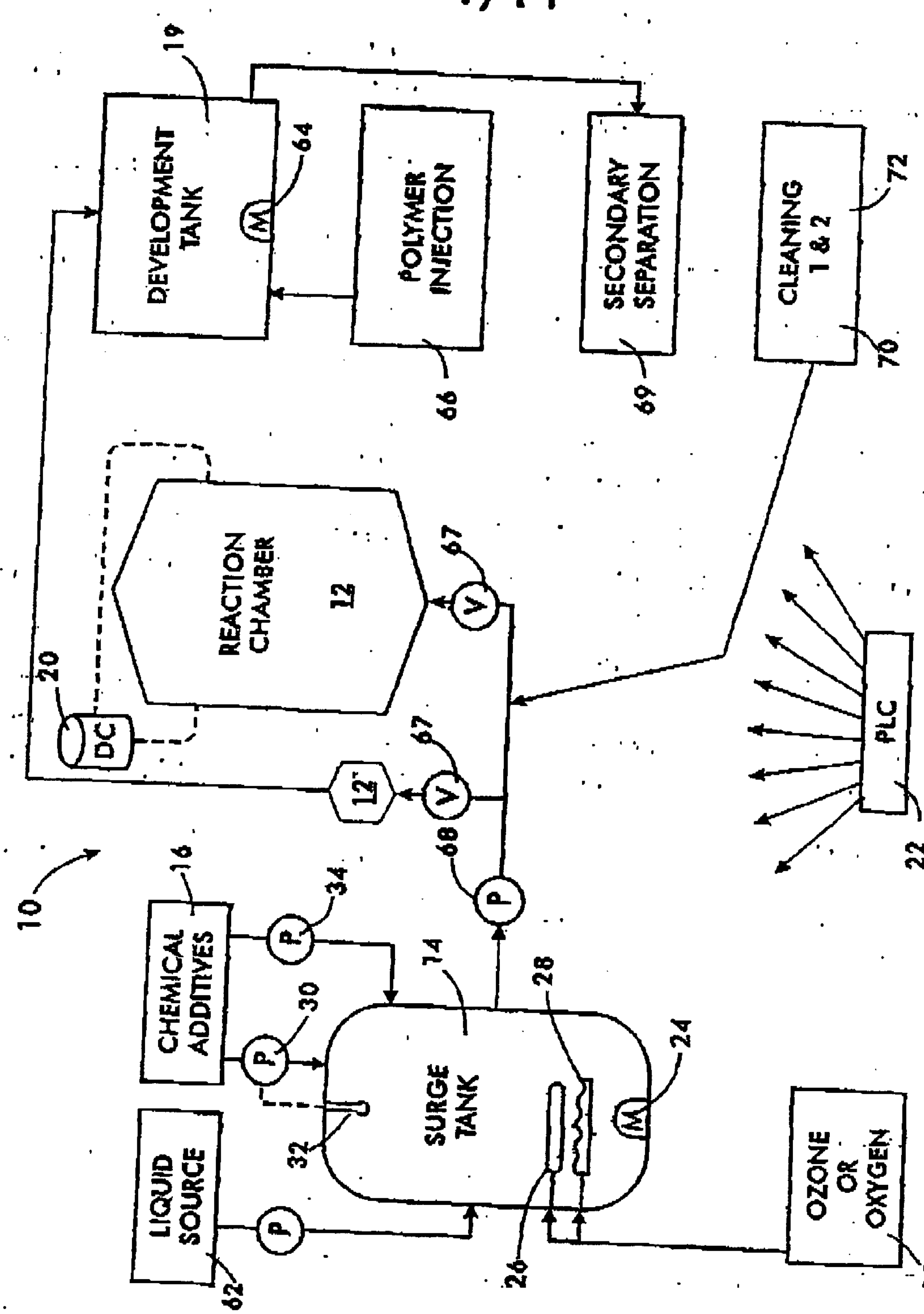
Direct all correspondence to: ☑	Customer Number or Bar Code Label 26092 PATENT TRADEMARK OFFICE	OR ☐	Correspondence address below
Name			
Address			
City		State	ZIP
Country	Telephone		Fax

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR :	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any]) F. William		Family Name or Surname GILMORE	
Inventor's Signature F. William Gilmore			Date 10/10/2002
Residence: City Castle Rock	State CO	Country USA	Citizenship US
Mailing Address 1433 Pine Ridge Lane			
City Castle Rock	State CO	ZIP 80104	Country USA
NAME OF SECOND INVENTOR:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])		Family Name or Surname	
Inventor's Signature			Date
Residence: City	State	Country	Citizenship
Mailing Address			
City	State	ZIP	Country

☐ Additional inventors are being named on the ____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

1/11



DEVELOPMENT TANK
19
64
M
POLYMER INJECTION
66
SECONDARY SEPARATION
69
CLEANING 1 & 2
72
70
REACTION CHAMBER
12
67
V
20
DC
12'
68
P
10
CHEMICAL ADDITIVES
16
34
30
14
SURGE TANK
28
24
32
LIQUID SOURCE
62
26
OZONE OR OXYGEN
18
PLC
22

Fig. 1

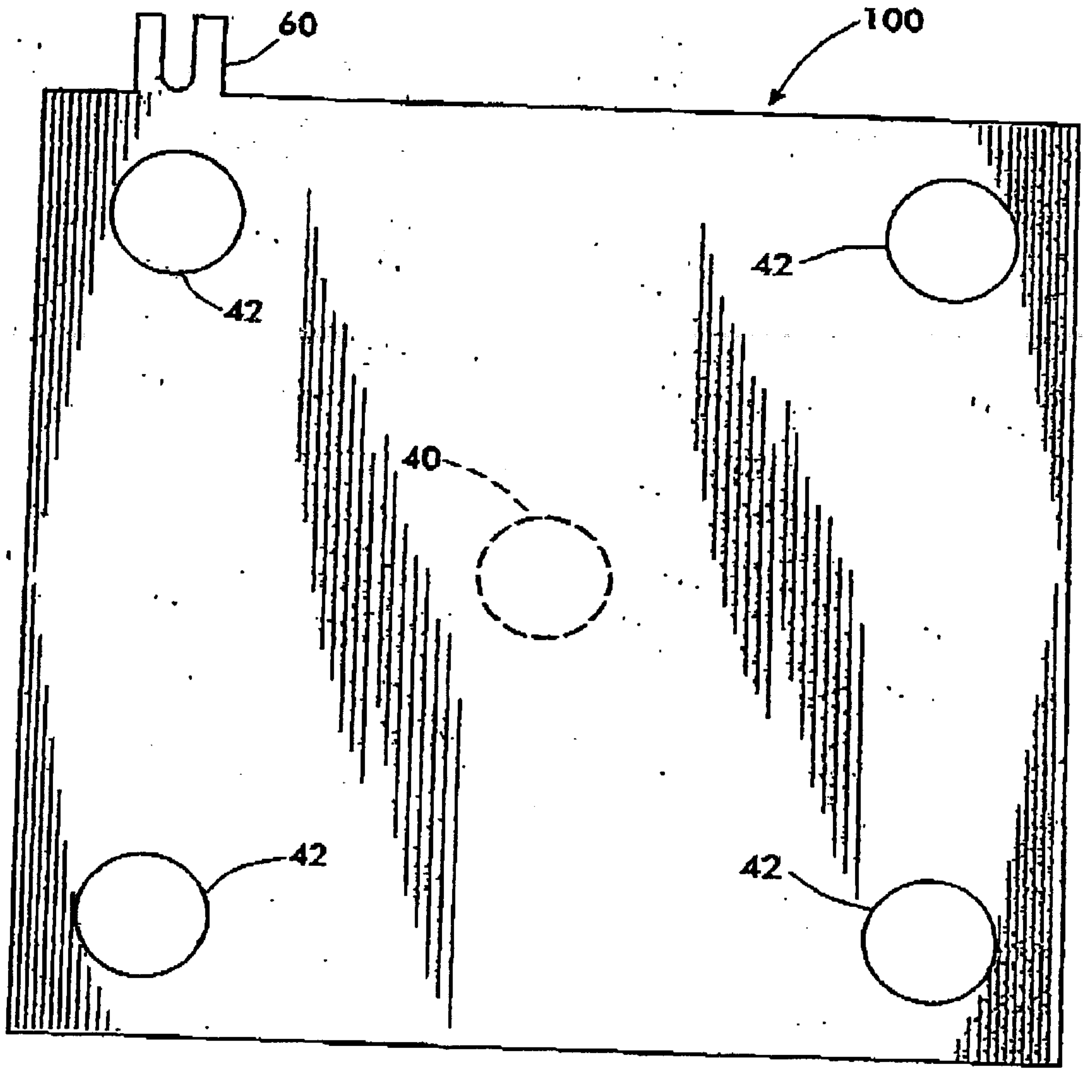


Fig. 2

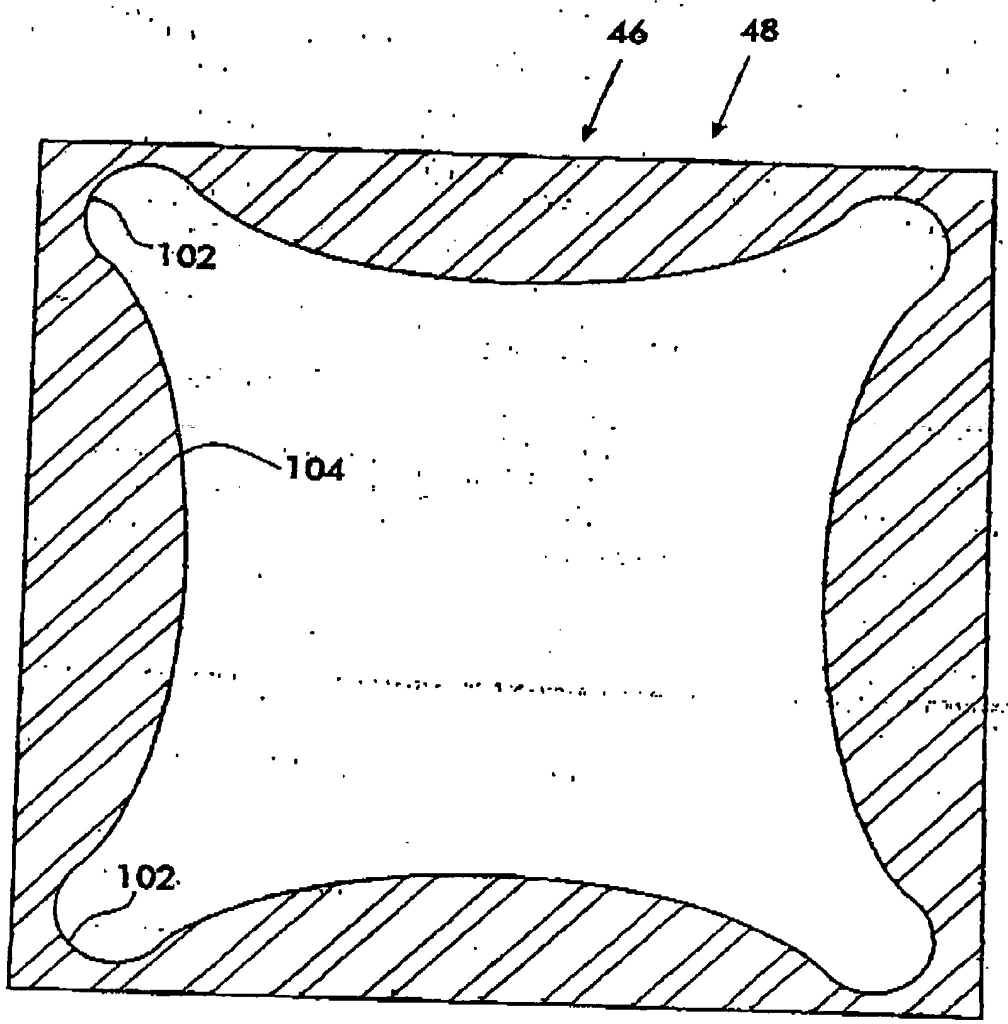


Fig. 3

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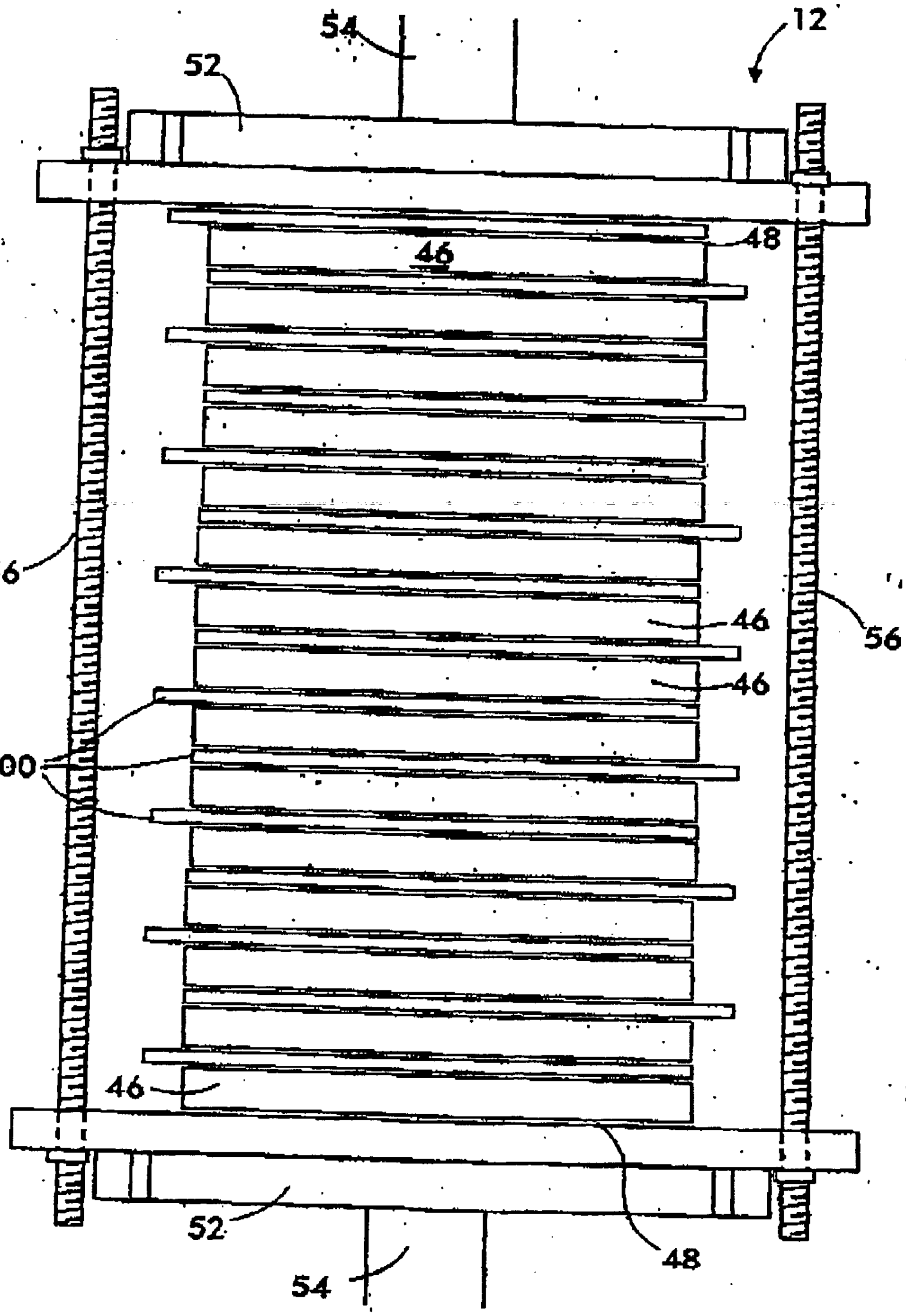

Fig. 4

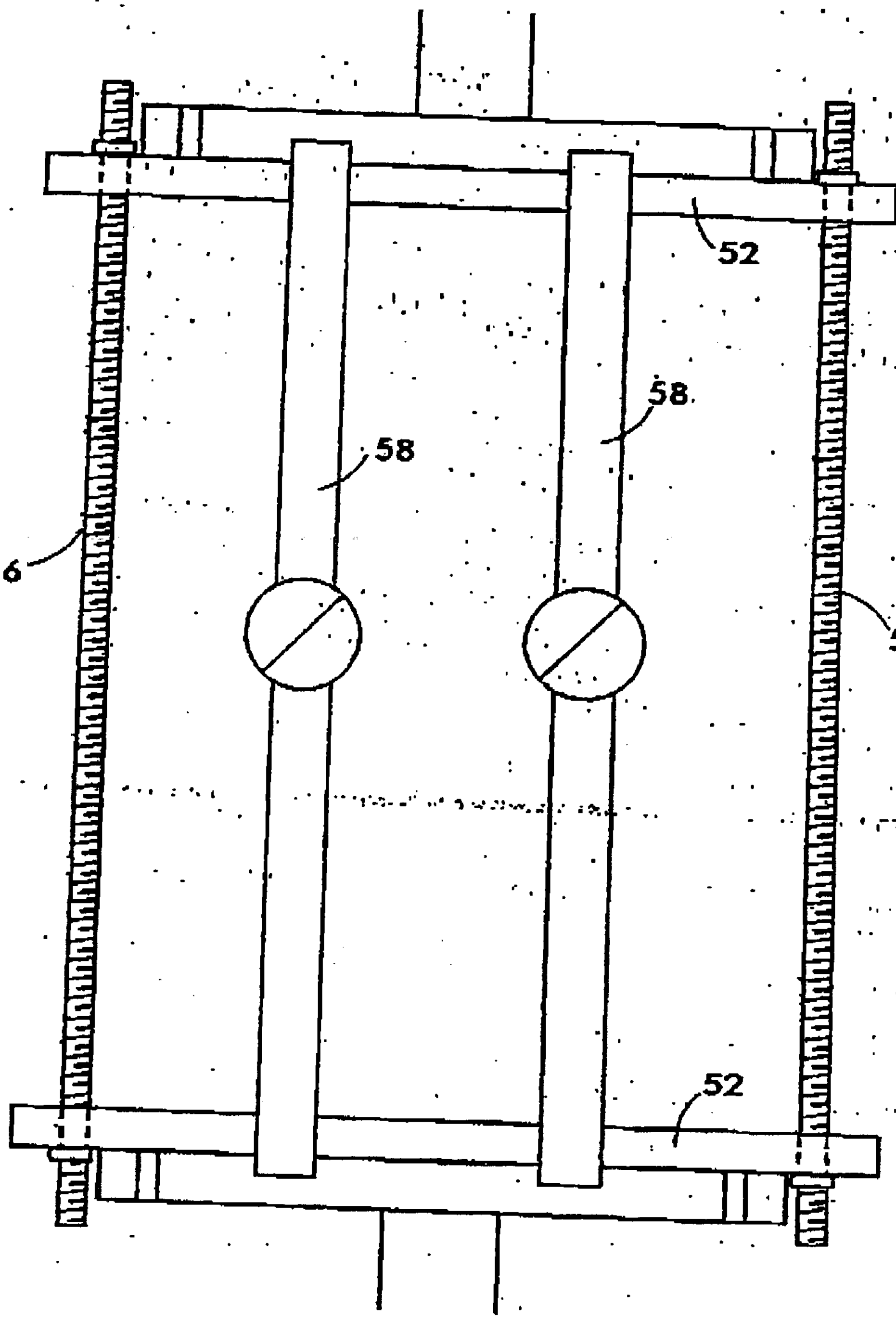

Fig. 5

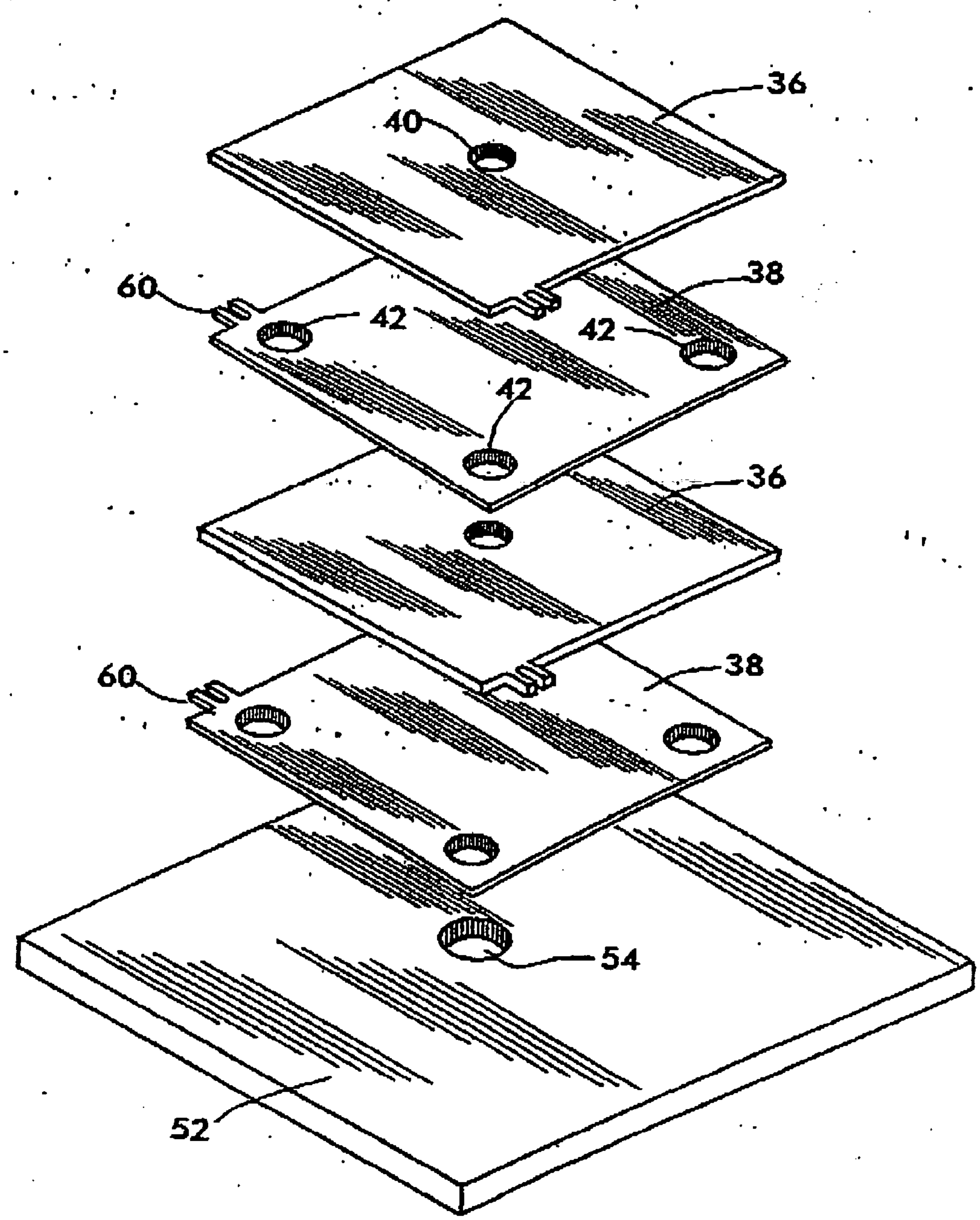

Fig. 6

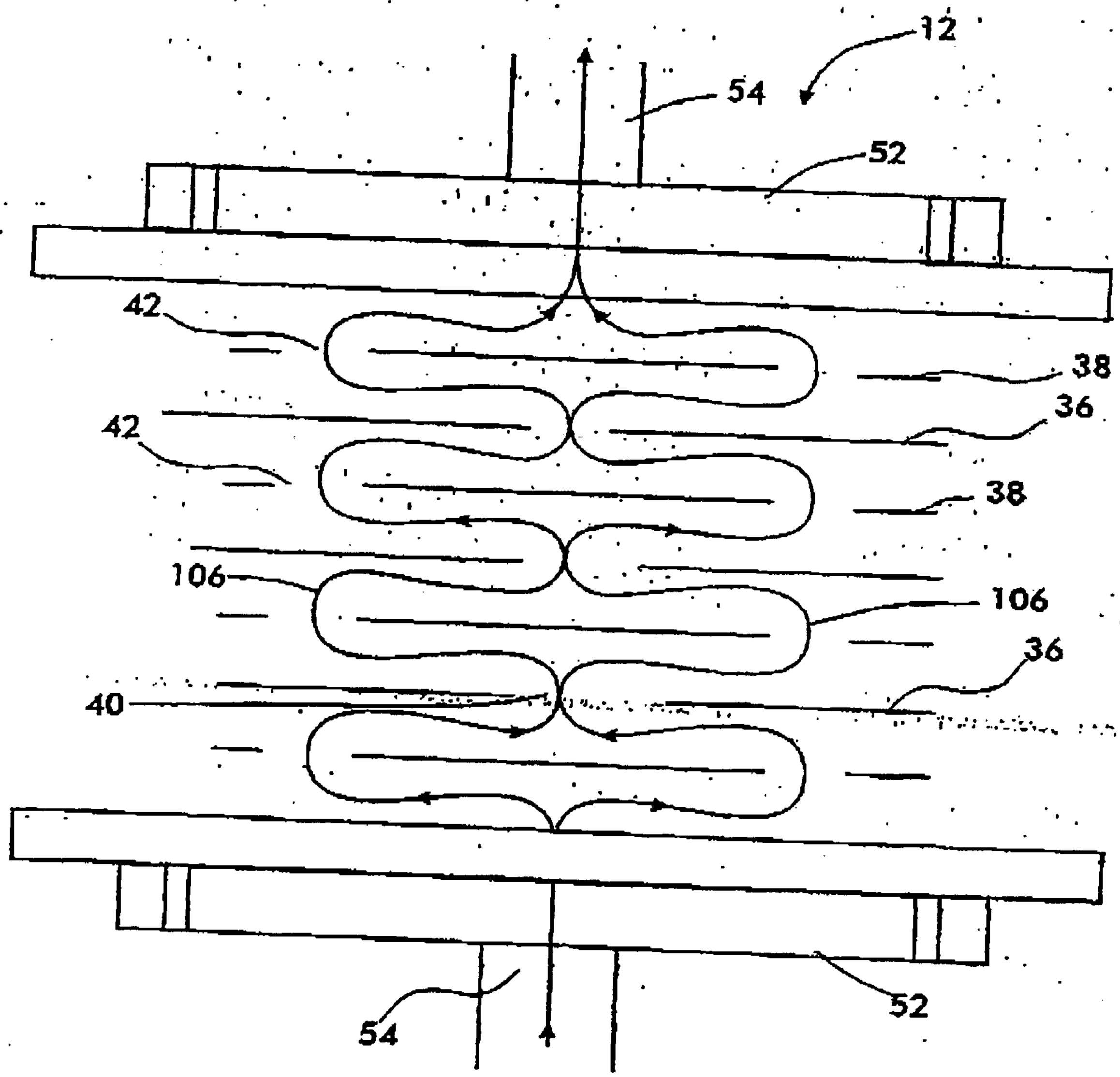

Fig. 7

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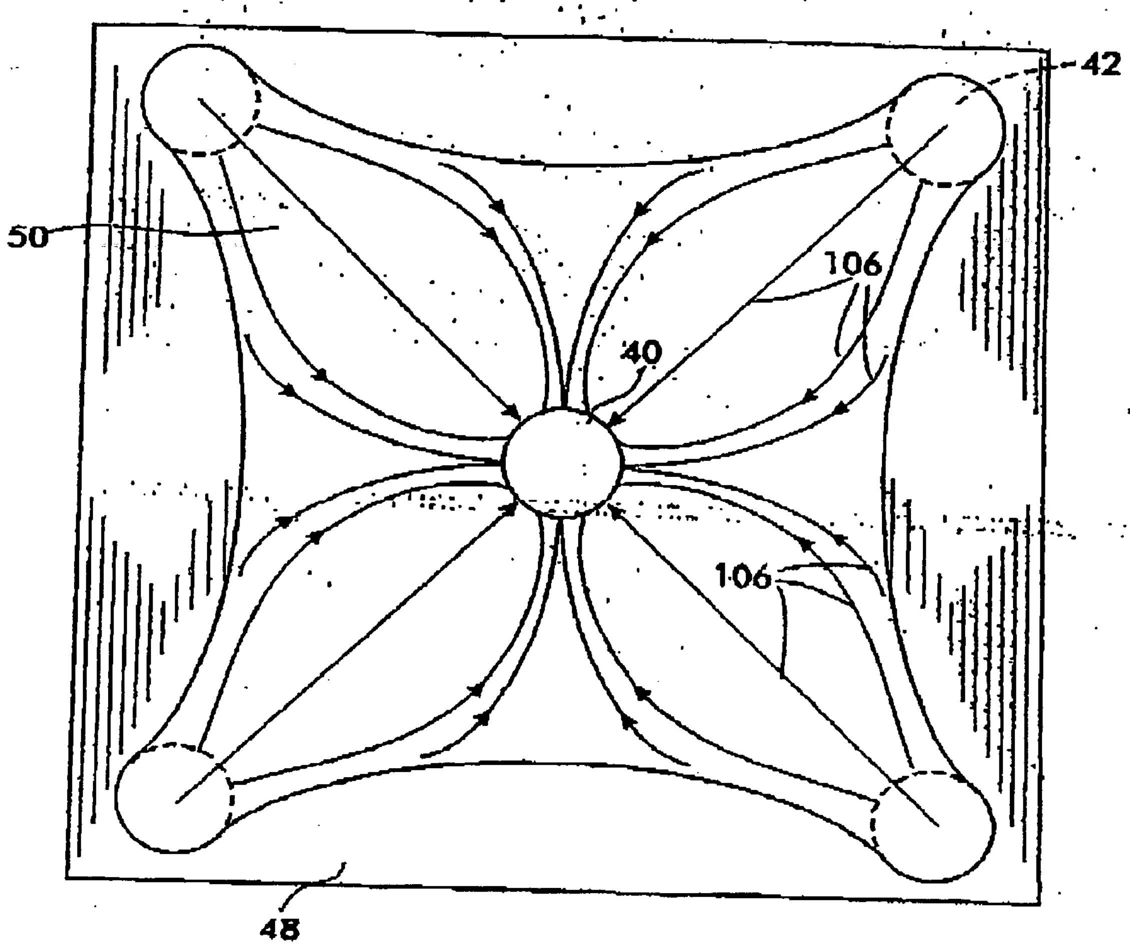

Fig. 8

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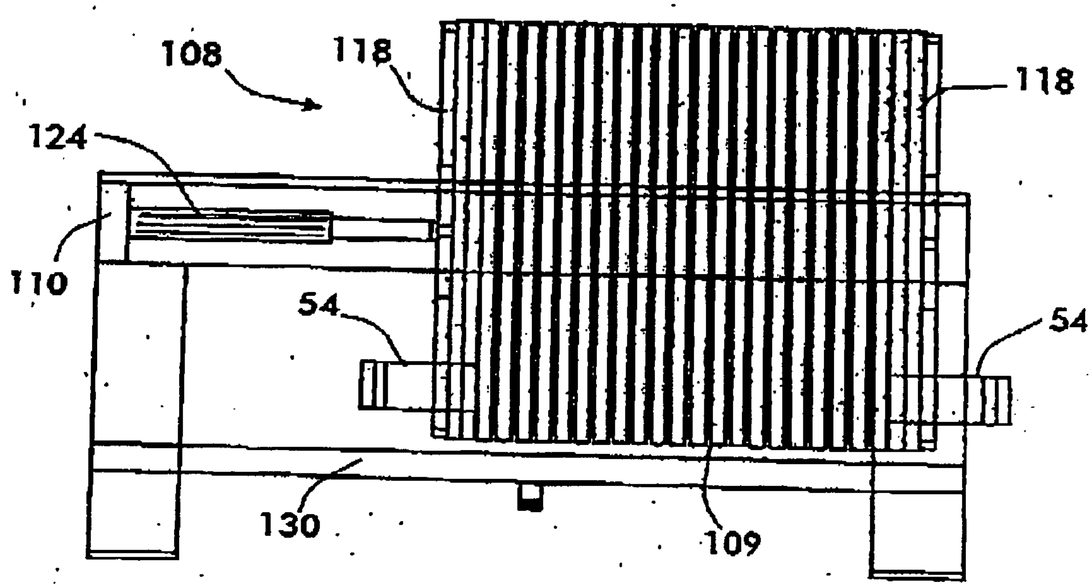

Fig. 9

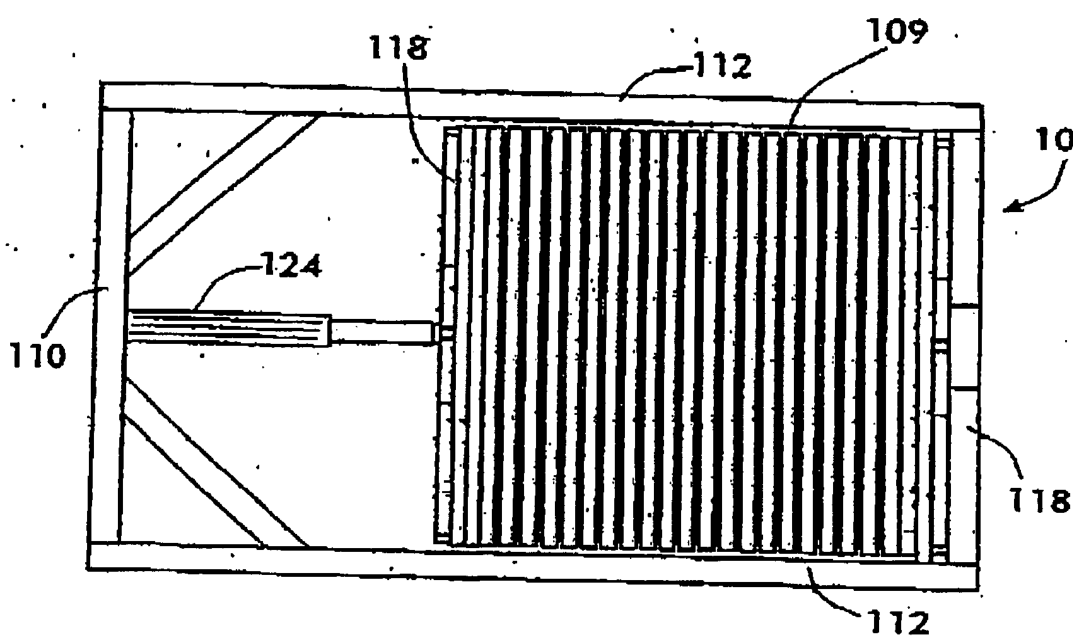

Fig. 10

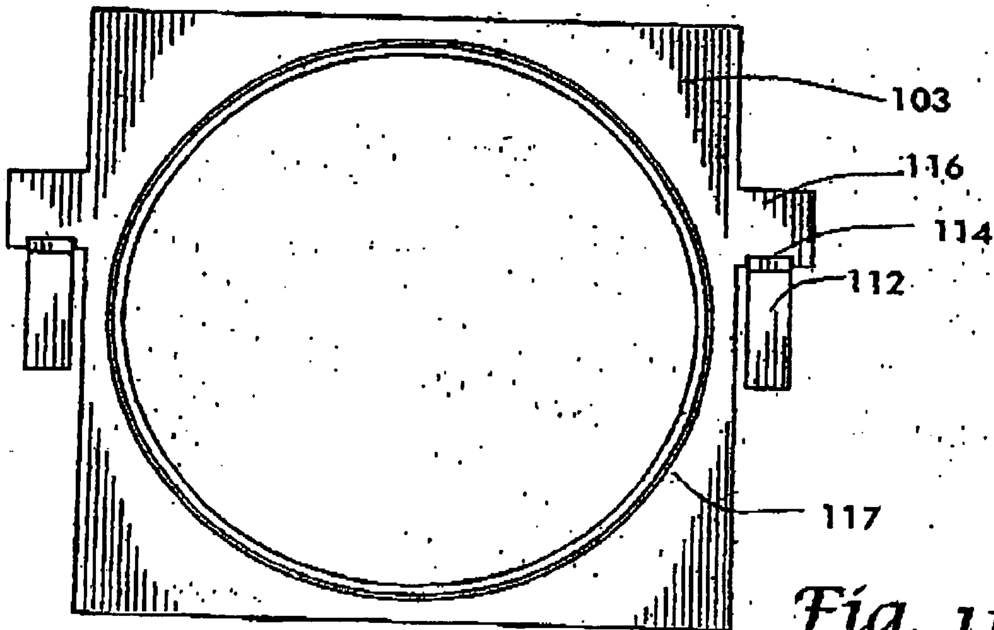

Fig. 11

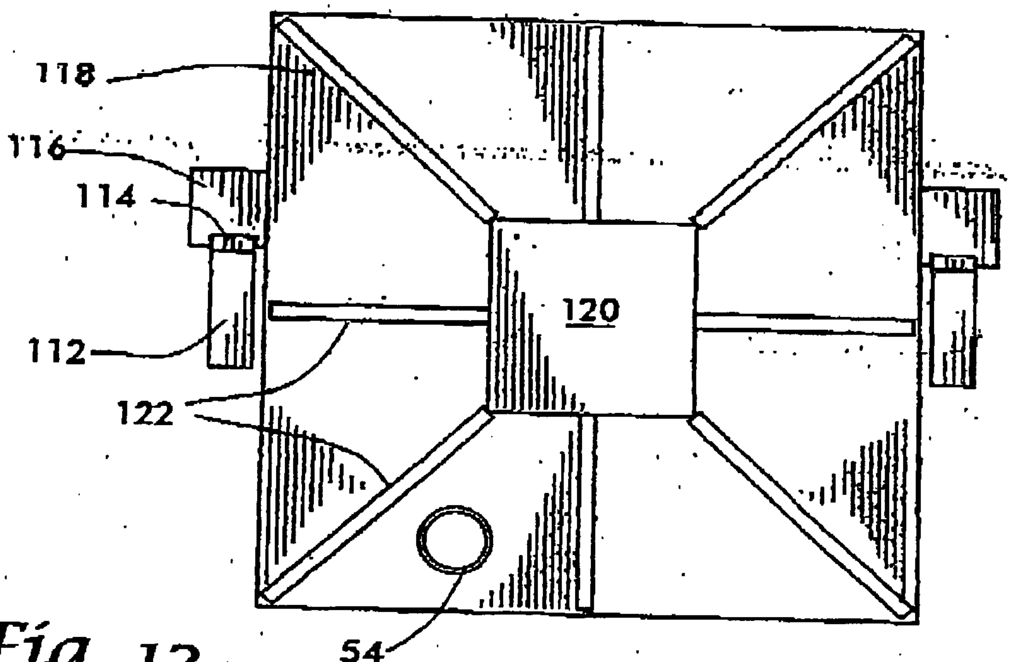

Fig. 12

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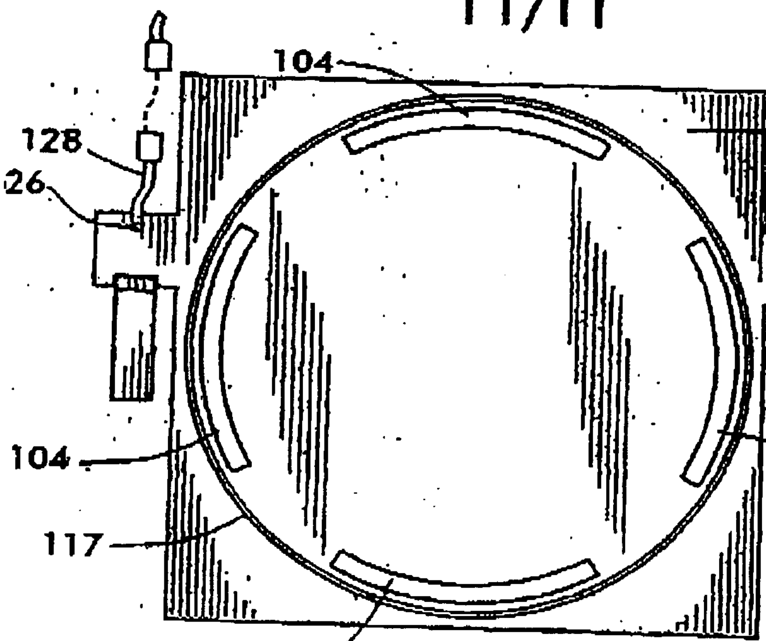

Fig. 13

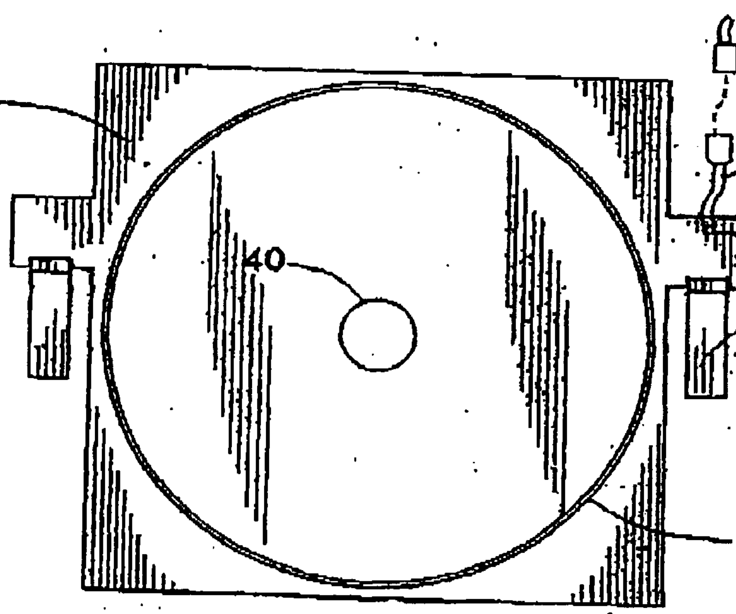

Fig. 14

Exhibit 1

Provisional Patent Application of F. William Gilmore
for "Electrocoagulation Reaction Chamber and Method"

Check for filing fee -- $80
Provisional Cover Sheet -- 1 page
Fee Transmittal -- 1 page
Specification - 16 pages
Drawings -- 8 sheets

Provisional - 10/12/01

This is Bill Gilmore's original provisional filing, filed before our disclosure To him in April, 2002, at The Trade Show in San Antonio. He subsequently Added our disclosure To This Provisional filing (filed for UTility PaTent on 10 October 2002).

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No.	EL651444755US

INVENTOR(S)

Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)
F. William	GILMORE	Denver, Colorado

☐ Additional inventors are being named on the ______ separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max)

Electrocoagulation Reaction Chamber and Method

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☑ Customer Number [ ] →

Type Customer Number here

26092

PATENT TRADEMARK OFFICE

OR

☐ Firm or Individual Name					
Address					
Address					
City		State		ZIP	
Country		Telephone		Fax	

ENCLOSED APPLICATION PARTS (check all that apply)

- ☑ Specification Number of Pages: 16
- ☑ Drawing(s) Number of Sheets: 8
- ☐ Application Data Sheet. See 37 CFR 1.76
- ☐ CD(s), Number
- ☑ Other (specify): Postcard

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

- ☑ Applicant claims small entity status. See 37 CFR 1.27.
- ☑ A check or money order is enclosed to cover the filing fees
- ☑ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 06-0788
- ☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): $80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

- ☑ No.
- ☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______

Respectfully submitted,

SIGNATURE [signature]

Date 10/12/2001

TYPED or PRINTED NAME Kyle W. Rost

REGISTRATION NO. (if appropriate) 27943

TELEPHONE 720-528-8863

Docket Number: GIL 1012

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Electrocoagulation Reaction Chamber and Method

TECHNICAL FIELD

The invention generally relates elements used in electrical and wave energy chemistry. More specifically, the invention relates to electrolytic apparatus composed of electrodes with an electrode supporting means consisting of a dielectric gasket or spacer. In a further aspect, the invention relates to an electrolytic apparatus and method that employ parallel plate electrodes to form plural separate treatment chambers or zones, with a feeding or withdrawing means providing a flow of liquid to be treated to the cells.

BACKGROUND ART

The practice of electrolysis upon aqueous solution results in production of water and an agglomerate. The latter can be separated from the water to produce a clean water. This process and its chemistry are well known, and many types of apparatus are used in the practice of it.

A primary problem in using an electrolytic process to produce clean water is a generally high cost of treatment. The direct cost of electricity is a significant part of the overall cost. The amount of electricity used in electrolytic processing is variable according to many factors in the design of an electrolytic reaction chamber. Design features that reduce electrical consumption are beneficial.

The cost of maintaining electrodes is another part of overall cost. Electrodes are consumed by the electrolytic reaction, but their consumption is basic to the chemistry of the reaction and is expected to occur over a predetermined time that is a function of reaction conditions. However, electrodes also can be fouled or short-circuited by deposit of reaction products. A fouled electrode becomes prematurely inefficient and can add to the amount of electricity consumed. Also, it will wear unevenly and will require premature

replacement or removal for cleaning, either of which adds to maintenance cost and down-time for the reaction chamber. A reaction chamber that keeps its electrodes clean during electrolytic processing is beneficial.

A reaction chamber is designed to accommodate many aspects of the electrolytic process. Primarily, the chamber must be effective and efficient in its performance. Thus, such aspects as electrode composition, spacing, and surface area are considered. Sustainable spacing between electrodes is important, so that adjacent electrodes do not contact each other and thereby produce a short circuit. The flow path through the electrodes is a significant factor, as the length of the path influences the speed with which the reaction must be performed and, thus, influences the electrical requirements of the chamber. Ease of replacing electrodes is significant, both in terms of maintenance cost and the down-time of a reaction chamber. These are only a few of the considerations that influence design of reaction chamber, which is a complex process.

One desirable configuration for a reaction chambers is known as the "filter press" design. Electrode plates are interleaved with dielectric spacers and gaskets to form an electrode stack. The stack is capped at its opposite ends by end plates, which are clamped together by suitable bolts or the like. The bolts are tightened to clamp the end plates, in turn squeezing together the elements in the stack of electrodes, gaskets and spacers. The filter press design is desirable because the stack of electrode plates is a unit that is easy to handle. Further, the spacing between plates is well controlled. The end plates can be configured for connection to inlet and outlet conduits for feeding and removing a process liquid, and the electrode plates can be suitably apertured or otherwise configured to define a flow path between the electrodes in the stack. A filter press design leads itself to the use of electrode plates having a square or rectangular shape, which is easily fabricated and, therefore, relatively low in cost.

United States Patent No. 1,541,947 to Hartman et al (1922) shows an early attempt at constructing such a filter press style reaction chamber. The electrodes are rectangular plates. Alternate plates are apertured near opposite narrower ends of the rectangle. Notably, two apertures are used at the perforated end of each rectangle. These apertures are transversely oblong, such that a considerable percentage of the perforated end is open

for liquid flow from one processing chamber or zone to the next. Thus, the stack the electrodes defines a sinuous. longitudinal flow path from edge-to-edge of the rectangle. with the direction of flow reversing in each successive zone as the process liquid flows through the series of processing zones.

Later advances in chamber design reveal that edge-to-edge sinuous flow across a rectangle is not uniform. Fluid in certain areas between the electrodes will be stagnant, allowing precipitates to foul nearby surfaces of the electrodes. United States Patent No. 4,124,480 to Stevenson discloses this problem in a filter-press design that employs edge-to-edge flow over rectangular plates in a stack. The electrode plates are slotted across the full width of alternating narrow ends to encourage the process liquid to flow over the full width of each electrode plate. However, even passing through a full width slot, the liquid stagnates along the edges of the plates, perhaps because of resistance induced by contact with the gasket or spacer located at such edges. Thus, it appears likely that longitudinal flow over a rectangular plate bounded by a side wall will be non-uniform and will result in fouling of certain areas of the plates.

The Stevenson patent also proposes a filter-press design using an alternate flow pattern with square electrode plates forming square treatment chambers. A first group of electrode plates are apertured at their center. A second group of electrode plates are relatively smaller in size than the first, such that they leave an almost continuous peripheral gap between each of the second group plates and the stack gaskets. In the second group, only the corners of the periphery are engaged between the gaskets and secure the second plates in the stack. The plates of the two groups are arranged in the stack in alternating sequence. The resulting flow path is from the center of a plate in the first group to the periphery of a plate in the second group, and vice versa.

However, it can be readily seen that such center-to-periphery and periphery-to-center flow will be non-uniform when square treatment chambers are used. In a stack of square plates, the shortest flow path, and likely the one with least resistance, is between the center hole of one plate and the midpoint along any of the four edges of a juxtaposed plate. Fouling is likely along the relatively longer flow paths near the corners of all plates in the

stack, with resulting uneven wear, poorly predictable process control, higher electricity usage, short circuits, and premature plate replacement or maintenance.

It is evident that circular plates would be no more successful in producing equal length radial flow paths. Fabricating and assembling a stack of circular plates is likely to be more expensive and will not solve the problems of premature fouling. Like square plates, circular plates must be configured with portions that engage the stack gaskets; and they must provide apertures or peripheral gaps that establish a sinuous flow path between plates. A circular shape is little better than a square one in meeting these two requirements. Uneven flow paths or stagnant areas are inevitable results. Circular plates are likely to behave similarly to square plates in suffering prematurely fouled areas.

It would be desirable to overcome the existing fouling problems in reaction chambers of the filter-press design. In particular, it would be desirable to have a chamber design producing predictable wear patterns in which fouling is not a substantial issue. Such a design would enable the reaction chamber to be operated with sustained process efficiency over a predictable interval. Such a predictable interval can be determined by calculating the consumption of the electrodes according to the reaction parameters imposed upon the chamber, rather than by the unpredictable time between loss of efficiency due to fouling. Maintenance or replacement operations can be performed at scheduled intervals, allowing a high degree of confidence that the electrocoagulation process will remain effective and efficient between such service.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as embodied and broadly described herein, the electrocoagulation chamber and method of this invention may comprise the following.

DISCLOSURE OF INVENTION

The objects, advantages and novel features of the invention shall be set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by the practice of the invention. The object and the advantages of the invention may be realized and attained by means of the instrumentalities and in combinations particularly pointed out in the appended claims.

The accompanying drawings, which are incorporated in and form a part of the specification illustrate preferred embodiments of the present invention, and together with the description, serve to explain the principles of the invention. In the drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of the overall electrocoagulation process.

Figure 2 is top plan view of a single electrode plate, showing the corner apertures in solid border, and showing an alternative central aperture in dashes.

Figure 3 is a top plan view of a single gasket or spacer.

Figure 4 is a side elevational view of an entire reaction chamber.

Figure 5 is a side elevational view of top and bottom pressure plates of a reaction chamber, showing compression members joining the pressure plates.

Figure 6 is a simplified exploded view of a portion of a reaction chamber, showing the alternating placement of electrode plates.

Figure 7 is a schematic view of the liquid flow path through a reaction chamber.

Figure 8 is a schematic view of the liquid flow path through a single treatment chamber of zone within a reaction chamber, showing the four corner apertures in one of the bordering electrode plates in dashed outline and showing the central aperture of a second bordering electrode plate in solid outline.

BEST MODE FOR CARRYING OUT THE INVENTION

The invention provides a non-fouling, self-cleaning, sinuous flow, electrolytic reaction chamber. A reaction chamber having a filter press structure is suitable for establishing and maintaining a stack of electrode plates that define a plurality of sequential treatment chambers or processing zones. The filter press style of reaction chamber is suited use in a system for treating water or other process fluids by electrocoagulation. The non-fouling characteristic of the reaction chamber is achieved by creating streamlined flow paths confining the process liquid to a highly predictable or known flow path through each zone. Thus, in a streamlined flow path, the available surface area of the electrodes is

limited to the shape of a predictable or known flow path characterized by a lack of stagnant areas.

The surface areas of the electrode can be conformed to the predictable or known flow path by several methods. First and preferred, the electrode plate is supplied in a size exceeding the size of the known or predictable flow path, and those portions exceeding the flow path are blocked. For example, the electrode plate may be generally square, which is not a desirable shape for a flow path and, therefore, contains surplus area.

The portions of the plate not a part of the predictable or known flow path are blocked from contact with the process liquid. Such blocking may be accomplished by supplying a gasket cut into a configuration that lies over the portion of the plate to be blocked. If a spacer is used in combination with a gasket between juxtaposed plates, the spacer may be cut in the same shape as the gasket so that it will support the gasket against the plate. When a stack of electrode plates, gaskets and spacers are compressed in a filter press style reaction chamber, the gaskets are snugly compressed against the plates, forming a liquid tight seal. The remaining, unblocked surface areas of the electrodes are in contact with the process fluid. Because the unblocked areas bound a known or predicted flow path, the unblocked areas are self-cleaned by the liquid flow. A second method of conforming the surface area of the electrode to the predictable or known flow path is by providing the electrode plates in the size and configuration of the flow path. For example, a flow path over a plate with apertures located in certain predetermined areas will define a predetermined shape. The electrode plates in a reaction chamber employing such a flow path can be cut in a matching size and predetermined shape, with supporting tabs or an additional edge portion at the periphery, as required to be engaged by gaskets. The gaskets and spacers are shaped to engage only the additional edge portions or supporting tabs of the specially shaped plates.

Empirical testing can determine the shape of flow paths in a reaction chamber. Initially, a reaction chamber employing electrode plates of a standard shape, such as a square, can be operated for a sufficient time to determine where fouling occurs. Such testing should be conducted with plates configured to define apertures in preselected locations and of size and spacing suited for process conditions. The flow paths appear on

the plates as clean areas, while areas prone to stagnation or low flow rates will be coated with deposits. The results of empirical testing establish the known or predictable flow paths for the reaction chamber. Thereafter, the gaskets and spacers can be shaped to block the plate areas not lying along the empirically determined flow path.

The invention provides a reaction chamber employing a flow path having a pattern causing the process fluid to clean the exposed electrode surfaces. The reaction chamber is of filter press construction, in which electrodes are arranged in a stack. As assembled in the stack, each electrode has a native geometric shape or outer edge contour that can be chosen for any desired characteristic, such as a physical shape suited to form a leak-proof stack, a shape that is convenient to fabricate and handle, or a shape that otherwise meets a requirement of a particular situation. Plates of regular symmetrical geometric shape relative to a center point tend to be good choices for sealing in a filter press chamber, easy handling, economy of manufacture and shipping, efficiency in utilization, and for forming predictable, regular flow paths. By way of example, such shapes include an equilateral triangle, square, circle, or other regular geometric shape. Elongated variations of these shapes, such as an ellipse, oval, rectangle, or an irregular shape are less desirable but are useable because the flow path ultimately will be determined by other factors, such as the relative positioning of apertures in juxtaposed plates.

A gasket separates each electrode from a juxtaposed electrode in the stack. Each gasket can be shaped at its outer edge to match the outer contour of the electrode plate. Optionally, each pair of juxtaposed electrodes are separated by two or more gaskets, and a spacer of predetermined thickness is interposed between two of the gaskets. The gaskets and spacers are planar and are of similar or substantially the same shape, such as if cut from sheet stock by the same cutting die. The gaskets lie generally over the peripheral margin of each electrode plate and have an open center area, which defines the uncovered central areas of each juxtaposed pair of electrodes. The uncovered area of the electrodes is the active area that contacts process liquid and participates in an electrolytic reaction with the process liquid. The uncovered area between each pair of elecrodes constitutes a separate treatment chamber or zone.

A means for establishing an electrical connection to each electrode plate allows each plate to carry a polar charge. For example, a conductive lug may extend from one or more edges of each square plate to beyond the outer edge of the gasket, providing a connection point for an electrical source. Adjacent plates may be oppositely charged by a D.C. electrical source, with the result that each treatment chamber or zone is defined by one positively charged plate and one negatively charged plate.

The electrodes define apertures allowing process liquid to pass from one zone to the next in the stack of electrodes. Each end of the electrode stack is capped by an end plate or pressure plate. The opposite pressure plates are joined together by elongated bolts, threaded rods, or other means for drawing the pressure plates toward each other. The pressure plates compress the electrode stack, primarily by compressing the gaskets to form a leak proof seal against the plates and spacers. The stack of electrode plates, gaskets, spacers and joined pressure plates together defines a reaction chamber. The pressure plates provide inlet and outlet fittings for transmitting process liquid through the reaction chamber. The apertures in the plates provide a flow passage for the process fluid to follow through the reaction chamber.

The apertures through the electrode plates establish a flow path passing sequentially through each of the treatment chambers or zones established between juxtaposed plates in the electrode stack. The flow pattern between sequential apertures is determined by the aperture positions and the configuration of the active or exposed electrode surfaces.

The plates in the stack consist of at least two groups, in which each group is configured with a different aperture pattern from the other group. The plates of the first group, or group one, each define a central and preferably circular aperture, located near the geometric center of the electrode plate. The plates of the second group, or group two, each define a plurality of peripheral apertures, preferably circular in shape.

In a plate shaped with corners or distal points, such as a square or triangular plate, an efficient usage of electrode plate area suggests locating one of these peripheral apertures near each of the corners or points of the electrode plate. Thus, in a square electrode plate, four peripheral apertures are used with one in or near each corner of the square.

In a circular plate or other plate without corners or points, the peripheral apertures are located near the peripheral edge of the plate. Preferably the peripheral apertures are equidistant from each other and from the center of the plate.

Plates of the two groups are arranged in alternating sequence in the electrode stack. Each treatment chamber or zone is bounded by one plate having a central aperture and one plate having a plurality of peripheral apertures. The flow path from zone to zone passes sequentially through the alternating hole patterns. Thus, in one of the zones the direction of liquid flow is from the center aperture of a plate from group one, spreading outwardly to the multiple peripheral apertures of a next sequential plate in the stack, which is from group two.

As the fluid enters the next zone, the direction of flow reverses. The flow pattern converges inwardly toward the center of the next sequential plate in the stack, which is from group one. This flow pattern of diverging and converging shape is repeated through the stack of electrode plates. The flow pattern causes turbulent flow of the process liquid, which encourages self-cleaning of the electrodes. The reversal of directions contributes to turbulent flow, which assists in cleaning the electrode plates and improves reaction speed and efficiency.

The almost every situation, the area of the aperture in a group one plate is expected to be unequal to the sum of the areas of the plural apertures in a group two plate. Consequently, the process liquid will undergo changes in velocity as it moves from one treatment chamber to the next. These velocity changes further contribute to turbulent flow.

The configuration of the inner edges of the spacers and gaskets is designed to block stagnant areas or areas of relatively low flow rate, such that the flow rate cannot sustain a clean condition of the electrode surfaces. Empirical testing shows that the inner edge of the gasket should have an undulated shape, consisting of trough portions and crest portions. The inner edge of the gasket defines a recess or concave trough at each of the peripheral apertures of a group two plate. The trough or recess is centered along the outside edge of one of the peripheral apertures. Thus, the number and positions of the troughs is equal to the number and positions of the peripheral apertures.

The contour of each trough portion tracks the outermost edge of a peripheral aperture up to about one-half the circumference of the aperture. The remaining half of an aperture's circumference is the inner most edge. This edge is open toward the center of the treatment chamber to allow process liquid to flow from the peripheral aperture of a group two plate toward the center aperture of a group one plate.

Neighboring trough portions of the undulated gasket edge are joined by a crest portion. Between troughs, the inner edge of the gasket defines a convex edge or crest centered on the central aperture of a group one plate. The apex of the convex edge typically will be spaced from the edge of the center aperture. A suitable spacing can be determined by the process of empirical testing. Often the crest will be separated from the central aperture by two or more diameters of the central aperture.

With reference to Fig. 1 of the drawings, a system 10 for treating a process liquid by electrocoagulation can employ a filter press style reaction chamber 12 using streamlined flow paths. On the upstream side of the chamber, the system can include a surge tank 14; a means for supplying chemical enhancement additives 16; and an ozone generator or oxygen source 18. On the downstream side of the chamber 12, the system can provide a development tank 19. In addition, the system is powered from a D.C. power supply 20 and controlled by a programmed processor such as a program logic controller (PLC) 22. In addition, the system may include supplemental standard equipment such as valves (V) and pumps (P) as required.

In a representative system, surge tank 14 holds a minimum of five minutes supply of process liquid, based on the applicable flow rate through the system. The surge tank contains a static mixer 24 for ensuring that any chemical additives 16 are thoroughly mixed with the process liquid. An ozone diffuser 26 or an oxygen micro-bubbler 28 are located near the bottom of the tank.

Chemical enhancement additives 16 commonly are acid or caustic solution for altering the pH of the process liquid. A metering pump 30 is controlled by a pH probe 32 in the surge tank for blending the acid or caustic chemical additives into the process liquid. Other additives can be added by a pump 34 controlled by a timer in the processor.

The ozone generator or oxygen source 18 is used to accelerate the oxidation rate of the electrolytic reaction. It also treats contaminants that may not be adequately treated in the reaction chamber. It is sized according to the flow rate of the system. Oxygen increases the overall oxidation rate of the electrolytic process. When ozone is used in place of oxygen, the rate of the overall oxidation reaction is increased by a factor of about thirteen. However, oxygen is less expensive and adequate for many applications.

With general reference to the drawings, a reaction chamber 12 can be constructed of square electrode plates alternating between group one plates 36 and group two plates 38. The group one plates have an aperture 40 at the center, while the group two plates have four apertures 42 distributed with one in each corner. The areas of the holes 40,42 are calculated to cause a pressure differential so that the velocity of the process liquid varies and causes turbulent flow as its passes between juxtaposed plates.

The plates are separated by spacers 46 formed of a chemically inert material such a polyvinylchloride. The spacers are selected for their predetermined thickness, which establishes a corresponding gap between the electrodes. A wide variety of spacer thickness can be preselected to accommodate the electrical requirements of the process liquid.

A gasket 48 is located between each plate and spacer for sealing the treatment chambers or zones 50 within the electrode stack. The gaskets and spacers are shaped by their inside edges to define streamlined flow paths in each treatment chamber 50. Gasket material typically is of a durometer in the range from sixty to seventy to produce a liquid tight seal without requiring adhesive. To a small degree, the gaskets influence the gap between electrodes. In addition, gaskets can be chosen with a preselected thickness to change the electrical characteristics of the reaction chamber.

The electrode stack is held in place by upper and lower pressure plates 52. The plates are equipped with fittings 54 for attaching inlet and outlet conduits to the chamber. The plates 52 are held together and compressed against the electrode stack by suitable compression rods that may include bolts, threaded rods, cam-locking fastener rods and the like. A set of four compression bolts 56 may connect the plates 52 at the four corners of the stack. In addition, another compression means such as a cam-locking fastener 58 may interconnect the plates 52 at the midpoint of each straight side of the stack. The periphery

of each electrode plate, gasket and spacer may be apertured to be threaded over the compression rods as an aid to the assembly of the electrode stack.

Each electrode plate carries a lug 60 for receiving a D.C. electrical connection. The lugs extend outside the gaskets on the outer surface of the electrode stack. A guard or cover can be placed over the reaction chamber to prevent inadvertent contact with the lugs or any other electrified portion of the reaction chamber. As a safety measure, the guard may be equipped with an interlocking switch for shutting off power to the system when the guard is removed.

The development tank 19 receives treated process liquid under pressure from the reaction chamber 12. The treated liquid resides in tank 19 while floc forms. A static mixer 64 in tank 19 enhances floc development. A polymer injection system 66 can be used where polymers will improve the settling process.

The D.C. power supply 20 receives A.C. power from the grid and transforms it to D.C. through a rectifier. The positive and negative sides of the D.C. supply are selectively connected to electrode blades in the reaction chamber. The D.C. supply can switch or reverse polarity to the electrodes. Periodically reversing polarity minimizes any buildup of oxides on the electrodes.

Overall system control resides in the program logic controller 22. Controlled features include liquid flow rate, operation of pumps and valves, and application of power to the reaction chamber electrode plates.

In operation, the system 10 is suited to treat process liquids, which may include waste water, drinking water, or process water. Process liquid is pumped from a source 62 to the surge tank 14 at a specified number of gallons per minute. The surge tank provides flooded suction for a feed pump 68. It also receives chemical additives 16 such as acid or caustic solution to adjust the pH of the process liquid. The static mixer 24 blends the additives and the process liquid. Ozone or oxygen 18 are injected into the process liquid to enhance the normal rate of oxidation that will take place in the reaction chamber 12.

Optionally, polymers can be injected into the liquid in the surge tank to improve the floc structure of certain process streams. For example, when thickening a stream of

sewage sludge, five percent of the normal polymer rate improved the resulting solids from seventeen percent to over twenty percent.

The process liquid from the surge tank is pumped under pressure through a connection to one or more reaction chambers 12. Each reaction chamber contains electrode plates formed of selected metals to provide the optimum ions for the appropriate chemical treatment of the process liquid. If multiple reaction chambers 12 are connected to the surge tank, individual reaction chambers can be placed on-line or off-line by suitable valves 67. This allows adjustment for varying flow rates and permits maintenance of individual chambers while processing continues in another chamber. The power supply 20 provides DC current to the electrodes, where the electricity passes through the process liquid and causes chemical reactions tending to form impurities into precipitates and flocs.

The treated process liquid is exits the reaction chamber and enters the development tank 19 while still under pressure. A residence time in the development tank allows floc to develop and be separated from the remaining portion of the treated process liquid, which often is clean water. Static mixer 64 in the development tank increases the rate of floc development and increases the efficiency of the polymer injection system 66. Liquid from the development tank can be pumped or gravity fed to a secondary separation system 69 such as a clarifier, filter press, filter, or the like.

Two systems clean the reaction chamber when it is inactive. One system 70 purges the chamber and then cleans it by pumping in acid or caustic solution that removes any build-up of contaminants on the electrode plates. A second system 72 purges the chamber with water to remove contaminants. The chamber is allowed to remain filled with clean water when it is idle. The water prevents oxidation on the electrodes.

The following example provides a detailed description of a preferred embodiment of the reaction chamber.

EXAMPLE

With reference to Fig. 2, a square electrode plate 100 has equal sides twelve inches (30.5 cm) in length. An electrical connection lug 60 extends from one of the sides at a position near one of the corners. The plate can be configured as either a group one or group two plate, according to the number and position of apertures formed in it. A central

aperture 40 is formed through each group one plate. Four corner apertures 42 are formed through each group two plate. The corner apertures are spaced from the edge of the plate by 0.53 inches. Each aperture 40,42 is three-quarters inch (19 mm) in radius. With an electrode plate eighteen inches per side, the preferred aperture radius is one inch. In an electrode plate twenty-four inches per side, the preferred aperture radius is one and one-half inches.

With reference to Fig. 3, a gasket 48 has a square outer edge twelve inches per side and is sized to fit over the electrode plate with edges aligned. The inside edge of the gasket is contoured in an undulating pattern. At a position over the corner aperture of the electrode, the gasket is shaped with a trough or recess 102 having a concave curve on a three-fourths inch radius. The concave curve is located on the gasket to align with the edge of a corner aperture 42 of a group two plate over approximately the outermost one-half of the circular aperture. In a gasket having eighteen inch side edges, the concave curve has a one inch radius; or with a gasket having twenty-four inch side edges, the curve has a one and one-half inch radius, or in each case conforming to the radius of the aperture in a mating electrode plate.

The inner edge of the gasket forms a crest or convex curve 104 between concave curves 102. The apex or center point of the crest is spaced two inches from the outer edge of the gasket. The end of the crest meeting the trough blends smoothly. In a gasket having eighteen inch side edges, the apex of the crest is three inches from the outer edge; or with a gasket having twenty-four inch side edges, the apex of the crest is four inches from the outer edge. Gaskets typically will be one-eighth inch in thickness.

Spacers 46 are shaped identically to gaskets 48 but vary in thickness. Suitable spacer thicknesses are one-quarter, three-eighths, one-half, three-fourths, and one inch.

With reference to Fig. 4, the reaction chamber 12 is formed by a stack of electrode plates arranged between top and bottom pressure plates 52. Each electrode has a gasket on both its top and bottom face, and a spacer 46 is interposed between the gaskets associated with juxtaposed electrodes. In addition, an end gasket 48 and an end spacer 46 are interposed between each of the pressure plates and each end electrode. Elongated compression members 56 join the pressure plates and allow them to be drawn toward each

other to compress the gaskets. With reference to Fig. 5, the assembled reaction chamber may include bolts or tightening rods 56 at each corner of the pressure plates. Alternate compression members such as cam-locking rods 58 may be located at one or more locations intermediate the corners.

With reference to Fig. 6, the electrode plates in the stack are arranged with group one and group two plates in alternating positions, with the connecting lugs in alternating directions. This eases connection of one electrical pole, such as the positive pole, to every other plate, such as all of the group one plates. The opposite pole, such as the negative pole, is connected to all group two plates. The pressure plates 52 are provided with a fitting or connecting aperture 54 for an inlet or outlet to the reaction chamber.

With reference to Fig. 7, the flow path through the reaction chamber 12 is sinuous. Liquid entering the chamber through one end is directed sequentially through alternating electrodes of groups one and two, in whatever order is selected during assembly of the chamber. The liquid follows a flow path 106 that variously diverges and converges as its traverses each treatment zone, as defined between two juxtaposed electrode plates.

With reference to Figs. 8, the flow within each zone is represented by the arrows 106. This flow is turbulent due to the varying contour of the zone. The liquid to change velocity frequently. For example, in passing through the four apertures 42 of a group two plate, the liquid sees an overall large passageway represented by the areas of the four apertures. The liquid can flow relatively slowly through such a large portal. However, when subsequently passing through the single aperture 40 of the juxtaposed group one plate, the liquid sees a relatively small portal represented by the area of the single aperture. The liquid must flow relatively faster through the smaller portal. Additional velocity changes result as the liquid passes from the narrow portions of a single zone to a wider portion, or vice versa. This turbulent flow improves the efficiency of the electrocoagulation process and helps to clean the electrode surfaces of accumulated precipitates or floc.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown

new material added here

and described, and accordingly all suitable modifications and equivalents may be regarded as falling within the scope of the invention as defined by the claims that follow.

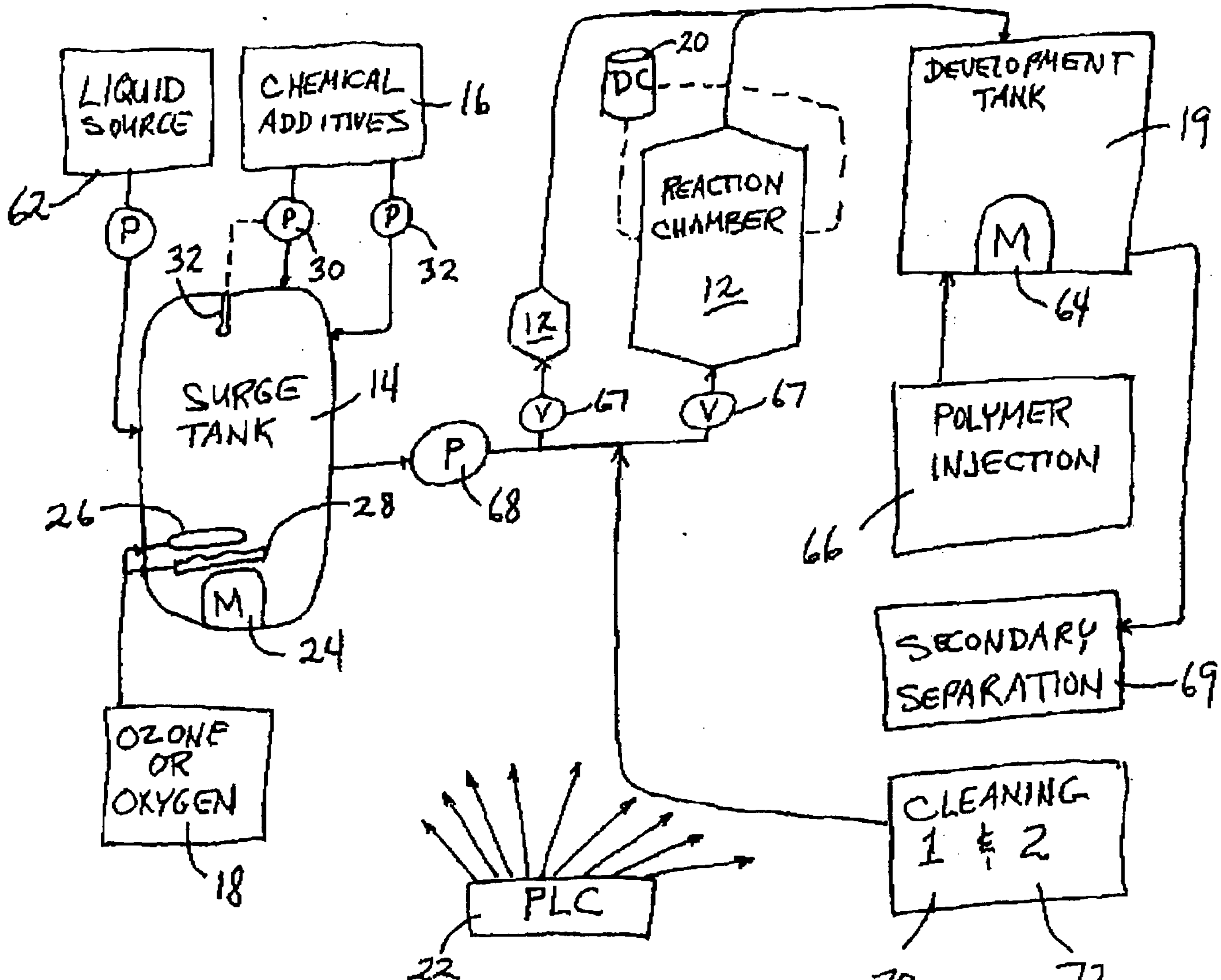
LIQUID SOURCE
62
CHEMICAL ADDITIVES
16
P
30
32
32
SURGE TANK
14
26
28
M
24
OZONE OR OXYGEN
18
P
68
V
67
12
20
DC
REACTION CHAMBER
12
DEVELOPMENT TANK
19
M
64
POLYMER INJECTION
66
SECONDARY SEPARATION
69
CLEANING 1 & 2
70
72
PLC
22

FIG. 1

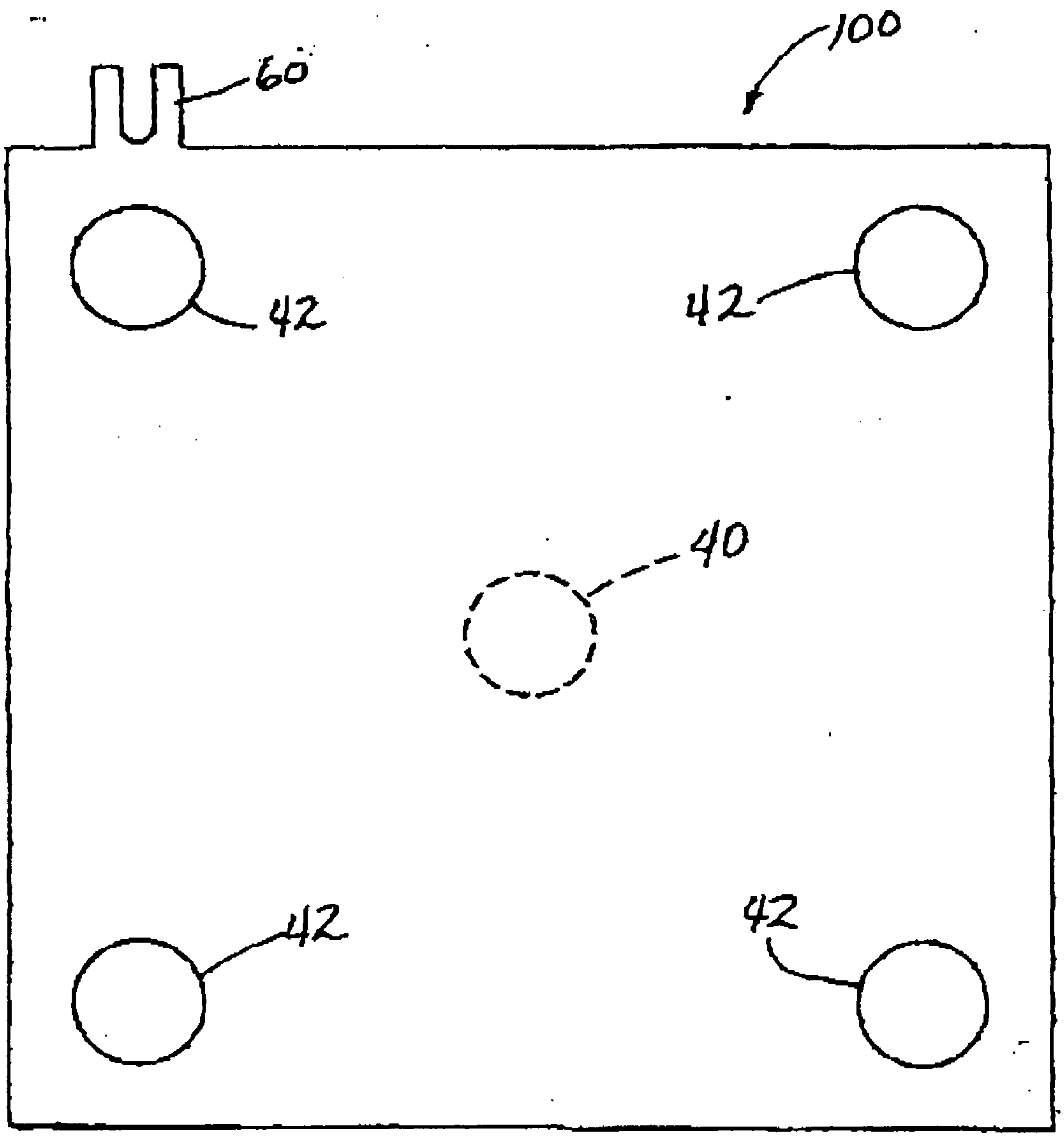

FIG. 2

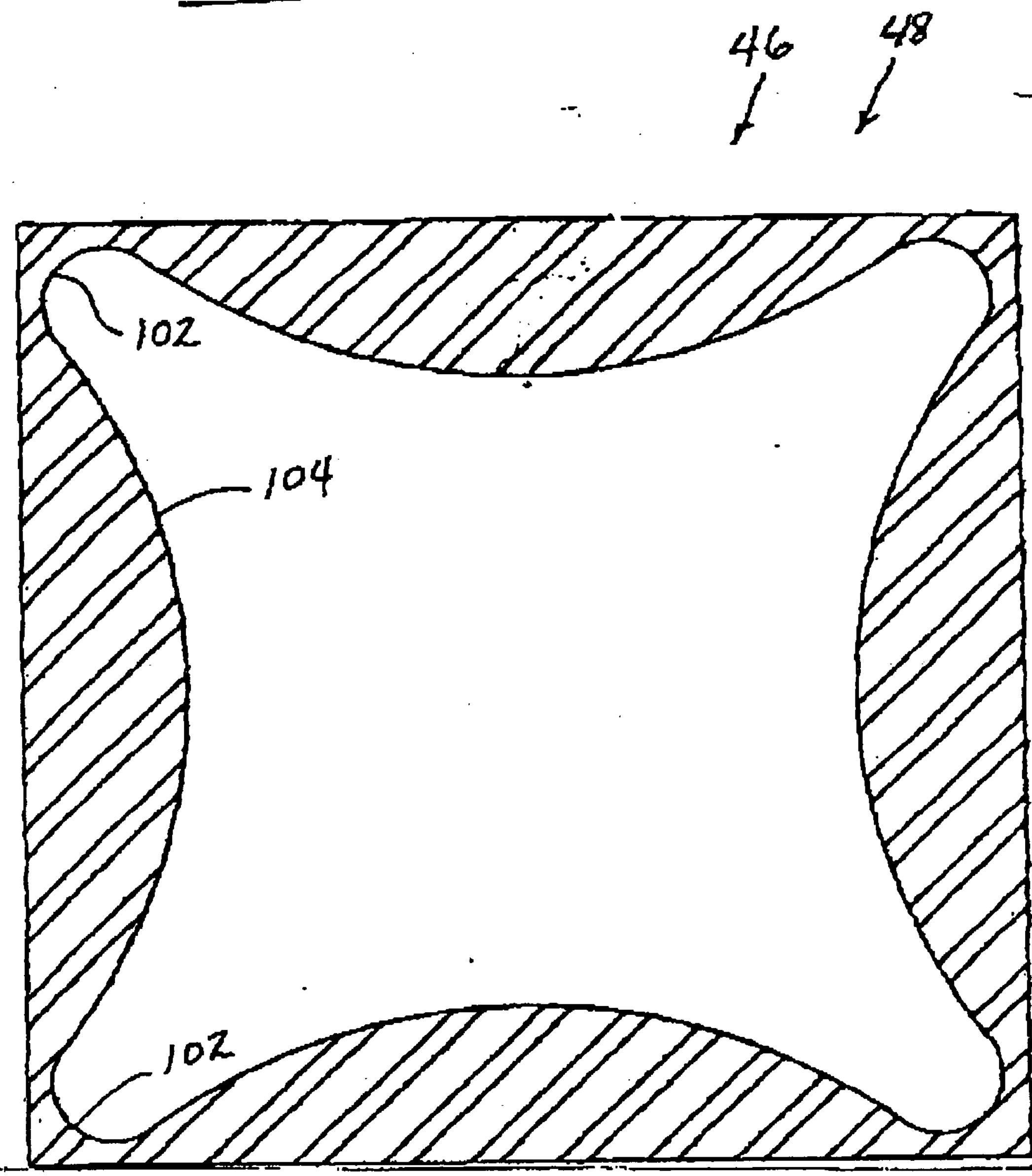

FIG. 3

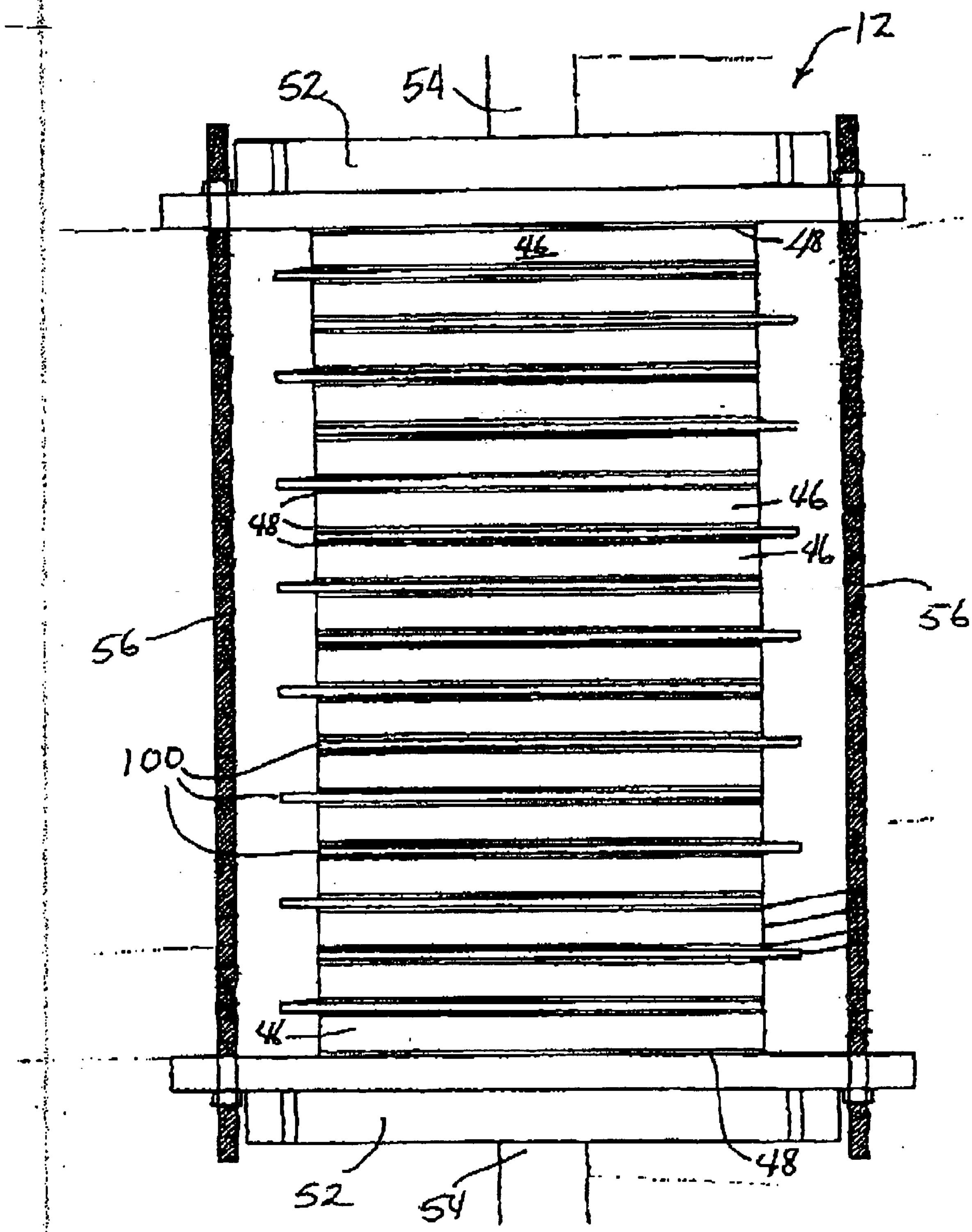

FIG. 4

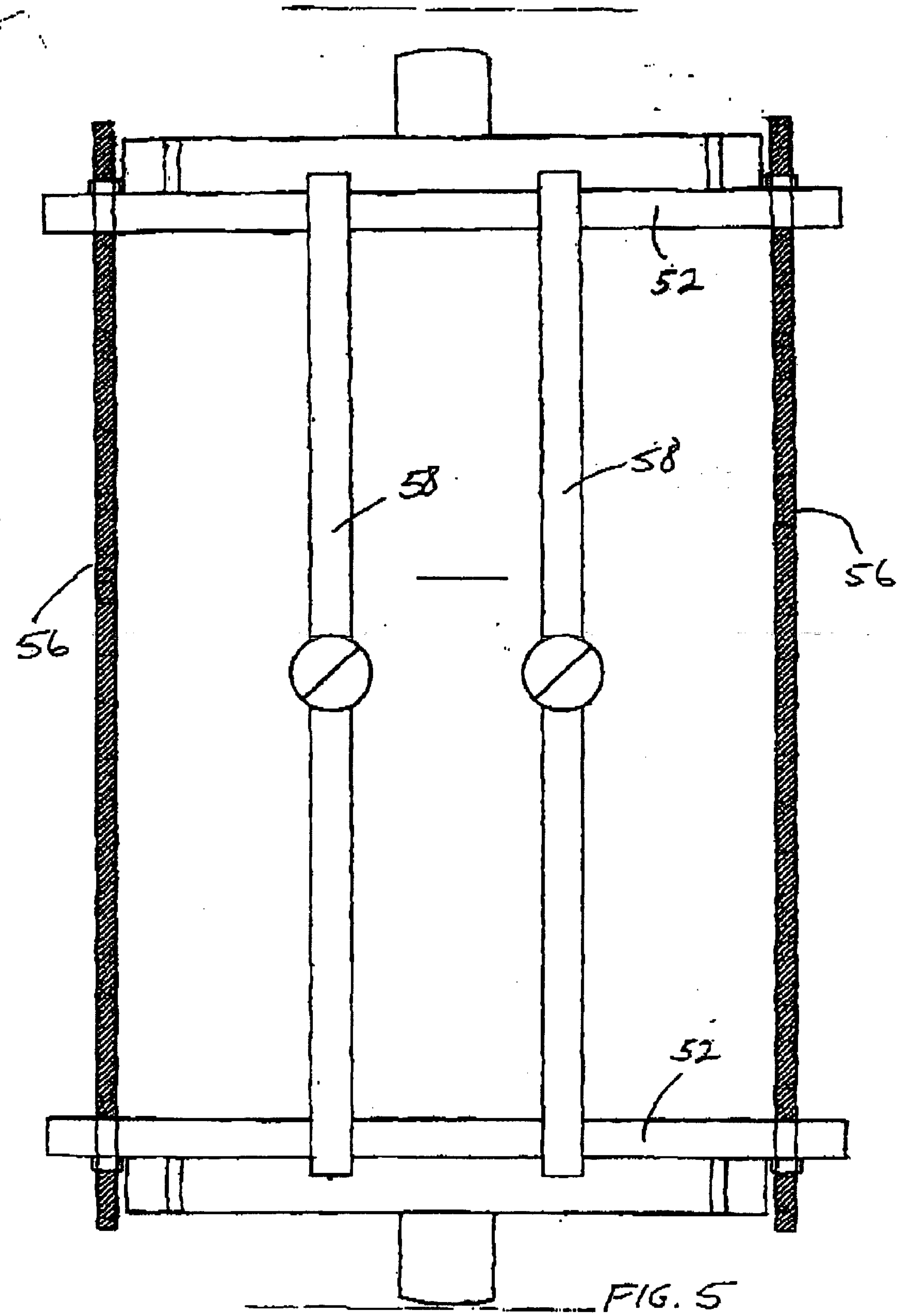

FIG. 5

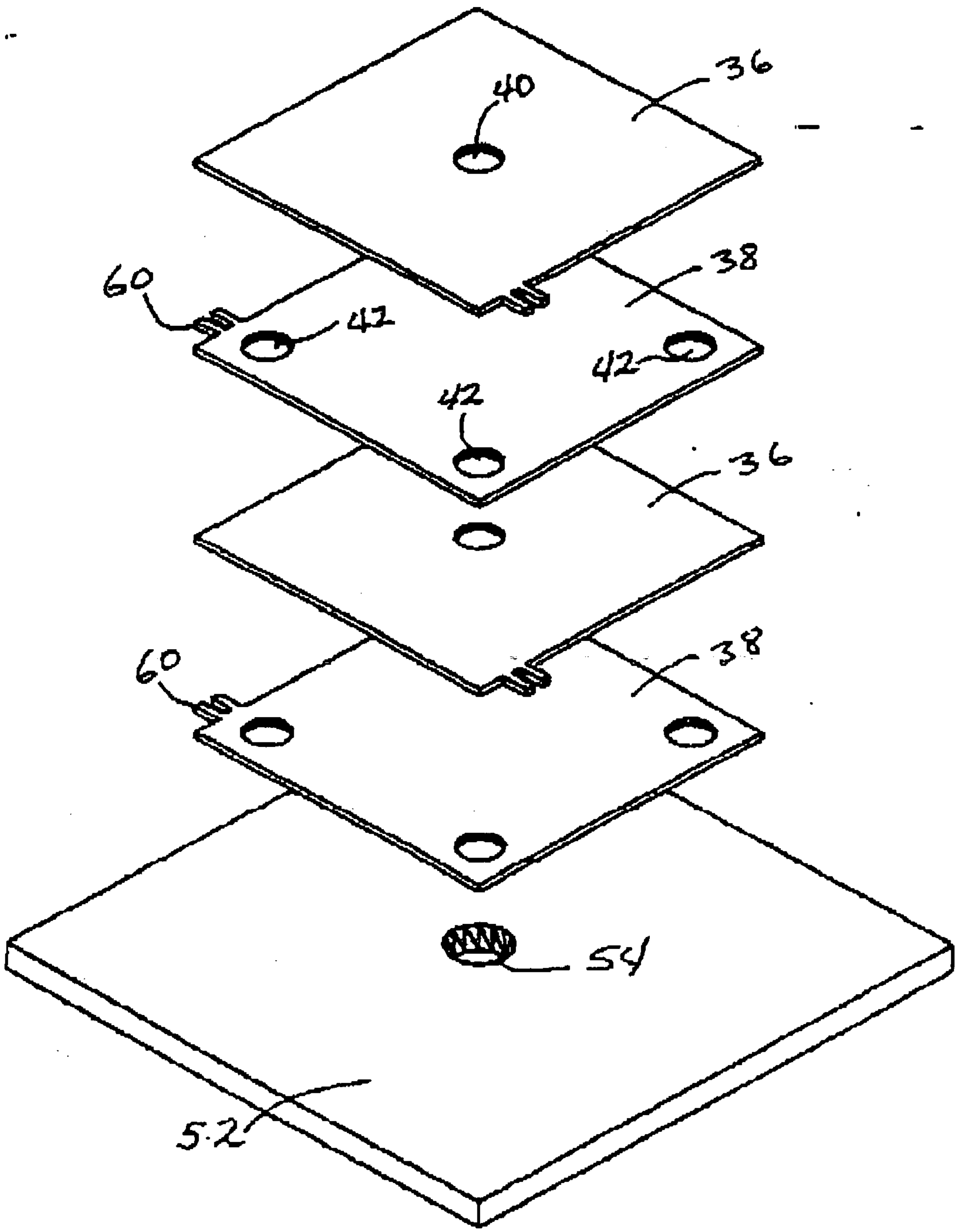

FIG. 6

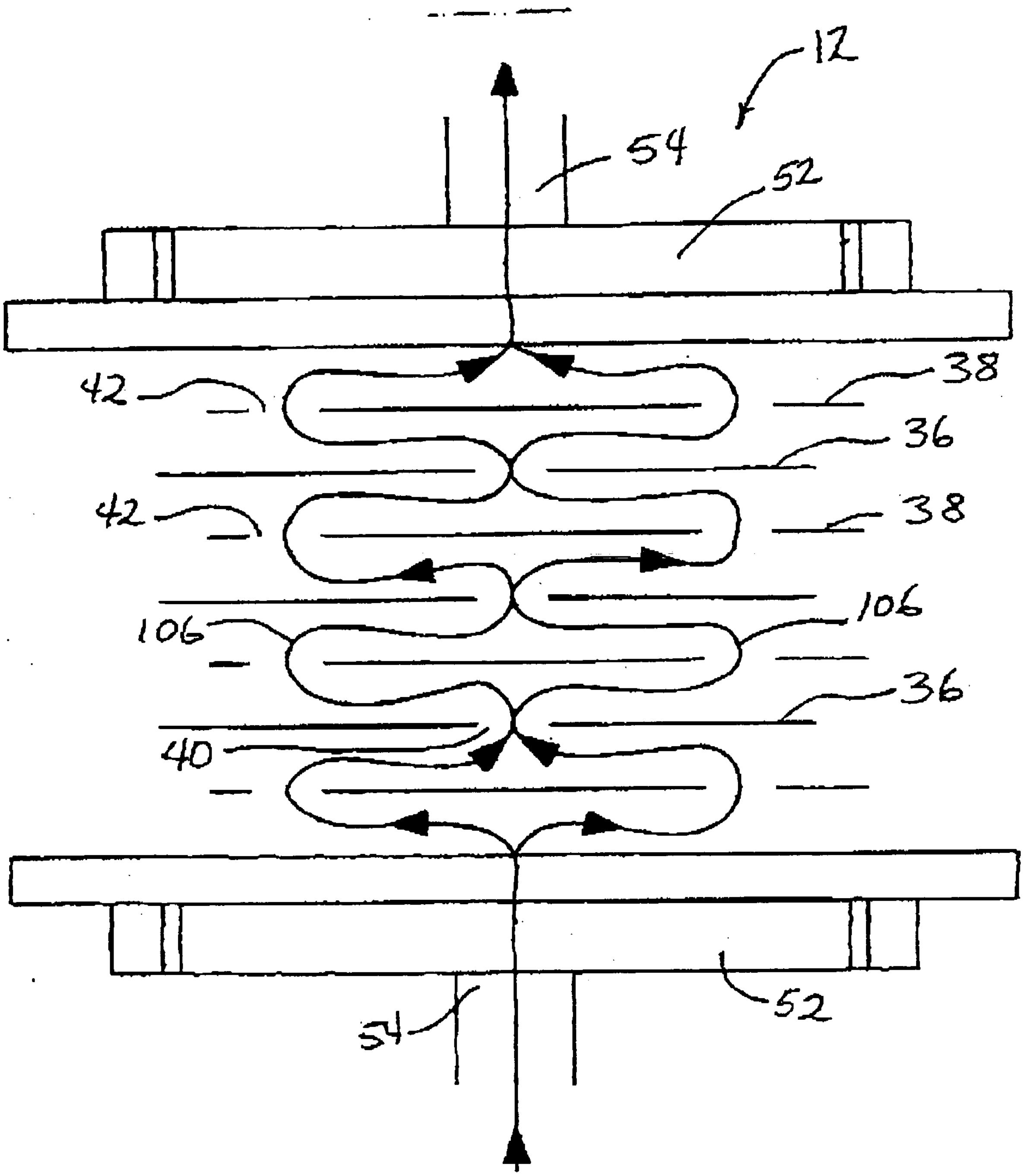

FIG. 7

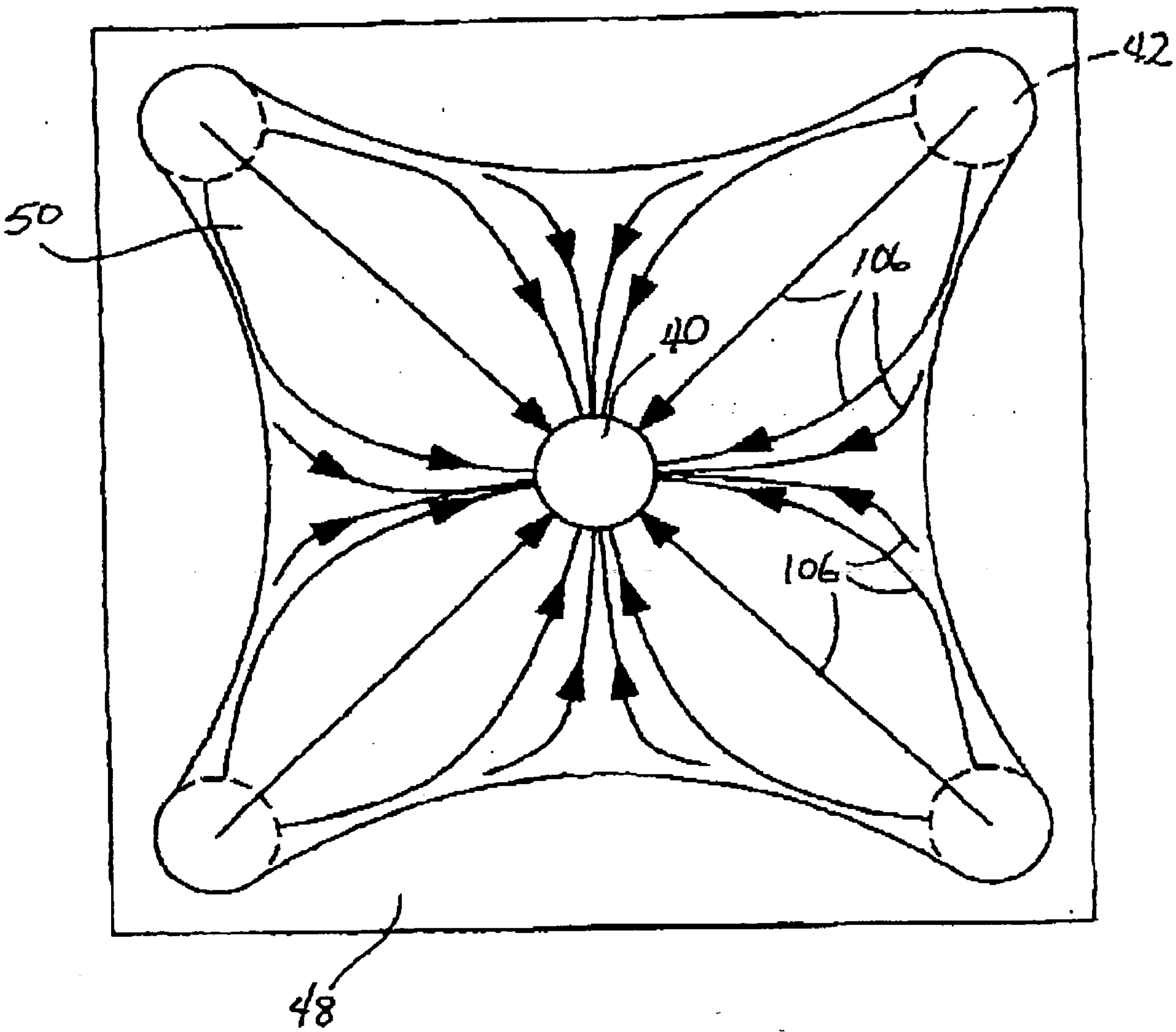

FIG 8

Exhibit 2

ATTachment 4

uTility filing

TRANSMITTAL LETTER TO THE UNITED STATES RECEIVING OFFICE

Date	10 October 2002
International Application No.	
Attorney Docket No.	GIL 1012

I. Certification under 37 CFR 1.10 (if applicable)

EO900209685US
Express Mail mailing number

10 October 2002
Date of Deposit

I hereby certify that the application/correspondence attached hereto is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Assistant Commissioner for Patents, Washington, D.C. 20231.

Signature of person mailing correspondence

Kyle W. Rost
Typed or printed name of person mailing correspondence

II. ☑ **New International Application**

TITLE: ELECTROCOAGULATION REACTION CHAMBER AND METHOD

Earliest priority date (Day/Month/Year): 12/10/2001

SCREENING DISCLOSURE INFORMATION: In order to assist in screening the accompanying international application for purposes of determining whether a license for foreign transmittal should and could be granted and for other purposes, the following information is supplied. (Note: check as many boxes as apply):

A. ☐ The invention disclosed was not made in the United States.

B. ☐ There is no prior U.S. application relating to this invention.

C. ☑ The following prior U.S. application(s) contain subject matter which is related to the invention disclosed in the attached international application. (NOTE: priority to these applications may or may not be claimed on form PCT/RO/101 (Request) and this listing does not constitute a claim for priority.)

application no.	60/329289	filed on	12 October 2001
application no.		filed on	

D. ☑ The present international application contains additional subject matter not found in the prior U.S. application(s) identified in paragraph C. above. The additional subject matter is found on pages 18-26 and ☑ DOES NOT ALTER ☐ MIGHT BE CONSIDERED TO ALTER the general nature of the invention in a manner which would require the U.S. application to have been made available for inspection by the appropriate defense agencies under 35 U.S.C. 181 and 37 CFR 5.1. See 37 CFR 5.15

III. ☐ **A Response to an Invitation from the RO/US. The following document(s) is(are) enclosed:**

A. ☐ A Request for An Extension of Time to File a Response

B. ☐ A Power of Attorney (General or Regular)

C. ☐ Replacement pages:

pages		of the request (PCT/RO/101)	pages		of the figures
pages		of the description	pages		of the abstract
pages		of the claims			

D. ☐ Submission of Priority Documents

Priority document		Priority document	

E. ☐ Fees as specified on attached Fee Calculation sheet form PCT/RO/101 annex

IV. ☐ **A Request for Rectification under PCT 91** ☐ **A Petition** ☐ **A Sequence Listing Diskette**

V. ☐ **Other (please specify):**

The person signing this form is the:

☐ Applicant

☑ Attorney/Agent (Reg. No.) 27943

☐ Common Representative

Kyle W. Rost, Reg. No. 27943
Typed name of signer

Signature

PTO-1382 (Rev. 08-1997)

U.S. Department of Commerce: Patent and Trademark Office

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	GIL 1012
First Inventor	GILMORE, F. William
Title	ELECTROCOAGULATION REACTION CHAMBER AND METHOD
Express Mail Label No.	EO900209884US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. [✔] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [✔] Applicant claims small entity status. See 37 CFR 1.27.
3. [✔] Specification [Total Pages 36]
   (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [✔] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 11]
5. Oath or Declaration [Total Pages 2]
   a. [✔] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] Application Data Sheet. See 37 CFR 1.76
7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program *(Appendix)*
8. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [✔] Information Disclosure Statement (IDS)/PTO-1449 [✔] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [✔] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: ____________

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: ______/______

Prior application information: Examiner: ______ Group Art Unit: ______

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[✔] Customer Number or Bar Code Label [redacted] or [ ] Correspondence address below

26092
PATENT TRADEMARK OFFICE

Name					
Address					
City		State		Zip Code	
Country		Telephone		Fax	

Name (Print/Type)	Kyle W. Rost	Registration No. (Attorney/Agent)	27943
Signature		Date	10/10/2002

TITLE OF INVENTION: ELECTROCOAGULATION REACTION CHAMBER AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS: Applicant claims the benefit of U.S. Provisional Patent Application Serial No. 60/329259 filed October 12, 2001.

TECHNICAL FIELD

The invention generally relates elements used in electrical and wave energy chemistry. More specifically, the invention relates to electrolytic apparatus composed of electrodes with an electrode supporting means consisting of a dielectric gasket or spacer. In a further aspect, the invention relates to an electrolytic apparatus and method that employ parallel plate electrodes to form plural separate treatment chambers or zones, with a feeding or withdrawing means providing a flow of liquid to be treated to the cells.

BACKGROUND ART

The practice of electrolysis upon aqueous solution results in production of water and an agglomerate. The latter can be separated from the water to produce a clean water. This process and its chemistry are well known, and many types of apparatus are used in the practice of it.

A primary problem in using an electrolytic process to produce clean water is a generally high cost of treatment. The direct cost of electricity is a significant part of the overall cost. The amount of electricity used in electrolytic processing is variable according to many factors in the design of an electrolytic reaction chamber. Design features that reduce electrical consumption are beneficial.

The cost of maintaining electrodes is another part of overall cost. Electrodes are consumed by the electrolytic reaction, but their consumption is basic to the chemistry of the reaction and is expected to occur over a predetermined time that is a function of reaction conditions. However, electrodes also can be fouled or short-circuited by deposit of reaction products. A fouled electrode becomes prematurely inefficient and can add to the amount of electricity consumed. Also, it will wear unevenly and will require premature replacement or removal for cleaning, either of

which adds to maintenance cost and down-time for the reaction chamber. A reaction chamber that keeps its electrodes clean during electrolytic processing is beneficial.

A reaction chamber is designed to accommodate many aspects of the electrolytic process. Primarily, the chamber must be effective and efficient in its performance. Thus, such aspects as electrode composition, spacing, and surface area are considered. Sustainable spacing between electrodes is important, so that adjacent electrodes do not contact each other and thereby produce a short circuit. The flow path through the electrodes is a significant factor, as the length of the path influences the speed with which the reaction must be performed and, thus, influences the electrical requirements of the chamber. Ease of replacing electrodes is significant, both in terms of maintenance cost and the down-time of a reaction chamber. These are only a few of the considerations that influence design of reaction chamber, which is a complex process.

One desirable configuration for a reaction chambers is known as the "filter press" design. Electrode plates are interleaved with dielectric spacers and gaskets to form an electrode stack. The stack is capped at its opposite ends by end plates, which are clamped together by suitable bolts or the like. The bolts are tightened to clamp the end plates, in turn squeezing together the elements in the stack of electrodes, gaskets and spacers. The filter press design is desirable because the stack of electrode plates is a unit that is easy to handle. Further, the spacing between plates is well controlled. The end plates can be configured for connection to inlet and outlet conduits for feeding and removing a process liquid, and the electrode plates can be suitably apertured or otherwise configured to define a flow path between the electrodes in the stack. A filter press design lends itself to the use of electrode plates having a square or rectangular shape, which is easily fabricated and, therefore, relatively low in cost.

United States Patent No. 1,541,947 to Hartman et al (1922) shows an early attempt at constructing such a filter press style reaction chamber. The electrodes are rectangular plates. Alternate plates are apertured near opposite narrower ends of the rectangle. Notably, two apertures are used at the perforated end of each rectangle. These apertures are transversely oblong, such that a considerable percentage of the perforated end is open for liquid flow from one processing chamber or zone to the

next. Thus, the stack of electrodes defines a sinuous, longitudinal flow path from edge-to-edge of the rectangle, with the direction of flow reversing in each successive zone as the process liquid flows through the series of processing zones.

Later advances in chamber design reveal that edge-to-edge sinuous flow across a rectangle is not uniform. Fluid in certain areas between the electrodes will be stagnant, allowing precipitates to foul nearby surfaces of the electrodes. United States Patent No. 4,124,480 to Stevenson discloses this problem in a filter-press design that employs edge-to-edge flow over rectangular plates in a stack. The electrode plates are slotted across the full width of alternating narrow ends to encourage the process liquid to flow over the full width of each electrode plate. However, even passing through a full width slot, the liquid stagnates along the edges of the plates, perhaps because of resistance induced by contact with the gasket or spacer located at such edges. Thus, it appears likely that longitudinal flow over a rectangular plate bounded by a side wall will be non-uniform and will result in fouling of certain areas of the plates.

The Stevenson patent also proposes a filter-press design using an alternate flow pattern with square electrode plates forming square treatment chambers. A first group of electrode plates are apertured at their center. A second group of electrode plates are relatively smaller in size than the first, such that they leave an almost continuous peripheral gap between each of the second group plates and the stack gaskets. In the second group, only the corners of the periphery are engaged between the gaskets and secure the second plates in the stack. The plates of the two groups are arranged in the stack in alternating sequence. The resulting flow path is from the center of a plate in the first group to the periphery of a plate in the second group, and vice versa.

However, it can be readily seen that such center-to-periphery and periphery-to-center flow will be non-uniform when square treatment chambers are used. In a stack of square plates, the shortest flow path, and likely the one with least resistance, is between the center hole of one plate and the midpoint along any of the four edges of a juxtaposed plate. Fouling is likely along the relatively longer flow paths near the corners of all plates in the stack, with resulting uneven wear, poorly predictable process control, higher electricity usage, short circuits, and premature plate replacement or maintenance.

It is evident that circular plates would be no more successful in producing equal length radial flow paths. Fabricating and assembling a stack of circular plates is likely to be more expensive and will not solve the problems of premature fouling. Like square plates, circular plates must be configured with portions that engage the stack gaskets; and they must provide apertures or peripheral gaps that establish a sinuous flow path between plates. A circular shape is little better than a square one in meeting these two requirements. Uneven flow paths or stagnant areas are inevitable results. Circular plates are likely to behave similarly to square plates in suffering prematurely fouled areas.

It would be desirable to overcome the existing fouling problems in reaction chambers of the filter-press design. In particular, it would be desirable to have a chamber design producing predictable wear patterns in which fouling is not a substantial issue. Such a design would enable the reaction chamber to be operated with sustained process efficiency over a predictable interval. Such a predictable interval can be determined by calculating the consumption of the electrodes according to the reaction parameters imposed upon the chamber, rather than by the unpredictable time between loss of efficiency due to fouling. Maintenance or replacement operations can be performed at scheduled intervals, allowing a high degree of confidence that the electrocoagulation process will remain effective and efficient between such service.

Further, it would be desirable to construct an electrocoagulation chamber in such a way that assembly and disassembly required very little time or technical skill. Thus, a chamber should allow streamlined insertion and removal of electrode plates or blades, as well as of spacers.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as embodied and broadly described herein, the electrocoagulation chamber and method of this invention may comprise the following.

DISCLOSURE OF INVENTION

Against the described background, it is therefore a general object of the invention to provide an improved structure for an electrocoagulation chamber, allowing rapid and simple assembly or disassembly, such as for maintenance.

Additional objects, advantages and novel features of the invention shall be set forth in part in the description that follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by the practice of the invention.

According to the invention, an electrocoagulation reaction chamber is constructed of a supporting frame providing a pair of laterally spaced, longitudinally extending, dielectric rails for supporting an electrode stack. The supporting frame carries first and second end plates. An electrode stack is located intermediate the end plates. The components of the stack include a dielectric spacer that is supported on the rails and provides a central spacer opening. The stack also includes first and second electrode plates that are supported on the rails. The first electrode plate is positioned between the first end plate and the spacer, and said second electrode plate is positioned between the second end plate and the spacer. One of the electrode plates has a central electrode aperture, while the other electrode plate has one or more peripheral apertures. Both of the electrode apertures are smaller in size than the opening in the spacer. A compression device selectively applies or releases a compressive force on the end plates for compressing or releasing the electrode stack. An inlet supplies process liquid into one end of the electrode stack, while an outlet discharges the process liquid from the opposite end of the electrode stack.

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate preferred embodiments of the present invention, and together with the description, serve to explain the principles of the invention. In the drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of the overall electrocoagulation process.

Figure 2 is top plan view of a single electrode plate, showing the corner apertures in solid border, and showing an alternative central aperture in dashes.

Figure 3 is a top plan view of a single gasket or spacer.

Figure 4 is a side elevational view of an entire reaction chamber.

Figure 5 is a side elevational view of top and bottom pressure plates of a reaction chamber, showing compression members joining the pressure plates.

Figure 6 is a simplified exploded view of a portion of a reaction chamber, showing the alternating placement of electrode plates.

Figure 7 is a schematic view of the liquid flow path through a reaction chamber.

Figure 8 is a schematic view of the liquid flow path through a single treatment chamber or zone within a reaction chamber, showing the four corner apertures in one of the bordering electrode plates in dashed outline and showing the central aperture of a second bordering electrode plate in solid outline.

Figure 9 is a schematic side view of a modified embodiment of a reaction chamber.

Figure 10 is a schematic top view of the reaction chamber of Fig. 9.

Figure 11 is a side elevational view of an end plate, showing an external side.

Figure 12 is a side elevational view of a spacer resting on dielectric rails.

Figure 13 is a side elevational view of an electrode plate with peripheral apertures, resting on dielectric rails, and showing the position of a juxtaposed O-ring seal in the electrode stack.

Figure 14 is a side elevational view of an electrode plate with a single central aperture, resting on dielectric rails, and showing the relative position of a juxtaposed O-ring seal in the electrode stack.

BEST MODE FOR CARRYING OUT THE INVENTION

The invention provides a non-fouling, self-cleaning, sinuous flow, electrolytic reaction chamber that is easily assembled, disassembled, and maintained. A reaction chamber having a filter press structure is suitable for establishing and maintaining a stack of electrode plates that define a plurality of sequential treatment chambers or processing zones. The filter press style of reaction chamber is suited use in a system for treating water or other process fluids by electrocoagulation. The non-fouling characteristic of the reaction chamber is achieved by creating streamlined flow paths that confine the process liquid to a highly predictable or known flow path through each zone. Thus, in a streamlined flow path, the available surface area of the electrodes is limited to the shape of a predictable or known flow path characterized by a lack of stagnant areas.

The surface areas of the electrode can be conformed to the predictable or known flow path by several methods. First and preferred, the electrode plate is supplied in a size exceeding the size of the known or predictable flow path, and those portions exceeding the flow path are blocked. For example, the electrode plate may be generally square, which is not a desirable shape for a flow path and, therefore, contains surplus area.

The portions of the plate not a part of the predicable or known flow path are blocked from contact with the process liquid. Such blocking may be accomplished by supplying a gasket cut into a configuration that lies over the portion of the plate to be blocked. If a spacer is used in combination with a gasket between juxtaposed plates, the spacer may be cut in the same shape as the gasket so that it will support the gasket against the plate. When a stack of electrode plates, gaskets and spacers are compressed in a filter press style reaction chamber, the gaskets are snugly compressed against the plates, forming a liquid tight seal. The remaining, unblocked surface areas of the electrodes are in contact with the process fluid. Because the unblocked areas bound a known or predicted flow path, the unblocked areas are self-cleaned by the liquid flow.

A second method of conforming the surface area of the electrode to the predicable or known flow path is by providing the electrode plates in the size and configuration of the flow path. For example, a flow path over a plate with apertures located in certain predetermined areas will define a predetermined shape. The electrode plates in a reaction chamber employing such a flow path can be cut in a matching size and predetermined shape, with supporting tabs or an additional edge portion at the periphery, as required to be engaged by gaskets. The gaskets and spacers are shaped to engage only the additional edge portions or supporting tabs of the specially shaped plates.

Empirical testing can determine the shape of flow paths in a reaction chamber. Initially, a reaction chamber employing electrode plates of a standard shape, such as a square, can be operated for a sufficient time to determine where fouling occurs. Such testing should be conducted with plates configured to define apertures in preselected locations and of size and spacing suited for process conditions. The flow paths appear on the plates as clean areas, while areas prone to stagnation or low flow

rates will be coated with deposits. The results of empirical testing establish the known or predictable flow paths for the reaction chamber. Thereafter, the gaskets and spacers can be shaped to block the plate areas not lying along the empirically determined flow path.

The invention provides a reaction chamber employing a flow path having a pattern causing the process fluid to clean the exposed electrode surfaces. The reaction chamber is of filter press construction, in which electrodes are arranged in a stack. As assembled in the stack, each electrode has a native geometric shape or outer edge contour that can be chosen for any desired characteristic, such as a physical shape suited to form a leak-proof stack, a shape that is convenient to fabricate and handle, or a shape that otherwise meets a requirement of a particular situation. Plates of regular symmetrical geometric shape relative to a center point tend to be good choices for sealing in a filter press chamber, easy handling, economy of manufacture and shipping, efficiency in utilization, and for forming predictable, regular flow paths. By way of example, such shapes include an equilateral triangle, square, circle, or other regular geometric shape. Elongated variations of these shapes, such as an ellipse, oval, rectangle, or an irregular shape are less desirable but are useable because the flow path ultimately will be determined by other factors, such as the relative positioning of apertures in juxtaposed plates.

A gasket separates each electrode from a juxtaposed electrode in the stack. Each gasket can be shaped at its outer edge to match the outer contour of the electrode plate. Optionally, each pair of juxtaposed electrodes are separated by two or more gaskets, and a spacer of predetermined thickness is interposed between two of the gaskets. The gaskets and spacers are planar and are of similar or substantially the same shape, such as if cut from sheet stock by the same cutting die. The gaskets lie generally over the peripheral margin of each electrode plate and have an open center area, which defines the uncovered central areas of each juxtaposed pair of electrodes. The uncovered area of the electrodes is the active area that contacts process liquid and participates in an electrolytic reaction with the process liquid. The uncovered area between each pair of electrodes constitutes a separate treatment chamber or zone.

A means for establishing an electrical connection to each electrode plate allows each plate to carry a polar charge. For example, an electrically conductive ear may extend from one or more edges of each square plate to beyond the outer edge of the gasket, providing a connection point for an electrical source. Adjacent plates may be oppositely charged by a direct current (DC) electrical source, with the result that each treatment chamber or zone is defined by one positively charged plate and one negatively charged plate.

The electrodes define apertures allowing process liquid to pass from one zone to the next in the stack of electrodes. Each end of the electrode stack is capped by an end plate or pressure plate. The opposite pressure plates are joined together by elongated bolts, threaded rods, or other means for drawing the pressure plates toward each other. The pressure plates compress the electrode stack, primarily by compressing the gaskets to form a leak proof seal against the plates and spacers. The stack of electrode plates, gaskets, spacers and joined pressure plates together defines a reaction chamber. The pressure plates provide inlet and outlet fittings for transmitting process liquid through the reaction chamber. The apertures in the plates provide a flow passage for the process fluid to follow through the reaction chamber.

The apertures through the electrode plates establish a flow path passing sequentially through each of the treatment chambers or zones established between juxtaposed plates in the electrode stack. The flow pattern between sequential apertures is determined by the aperture positions and the configuration of the active or exposed electrode surfaces.

The plates in the stack consist of at least two groups, in which each group is configured with a different aperture pattern from the other group. The plates of the first group, or group one, each define a central and preferably circular aperture, located near the geometric center of the electrode plate. The plates of the second group, or group two, each define a plurality of peripheral apertures, preferably circular or arcuate in shape.

In a plate shaped with corners or distal points, such as a square or triangular plate, an efficient usage of electrode plate area suggests locating one of these peripheral apertures near each of the corners or points of the electrode plate. Thus,

in a square electrode plate, four peripheral apertures are used with one in or near each corner of the square.

In a circular plate or other plate without corners or points, the peripheral apertures are located near the peripheral edge of the plate. Preferably the peripheral apertures are equidistant from each other and from the center of the plate.

Plates of the two groups are arranged in alternating sequence in the electrode stack. Each treatment chamber or zone is bounded by one plate having a central aperture and one plate having a plurality of peripheral apertures. The flow path from zone to zone passes sequentially through the alternating hole patterns. Thus, in one of the zones the direction of liquid flow is from the center aperture of a plate from group one, spreading outwardly to the multiple peripheral apertures of a next sequential plate in the stack, which is from group two.

As the fluid enters the next zone, the direction of flow reverses. The flow pattern converges inwardly toward the center of the next sequential plate in the stack, which is from group one. This flow pattern of diverging and converging shape is repeated through the stack of electrode plates. The flow pattern causes turbulent flow of the process liquid, which encourages self-cleaning of the electrodes. The reversal of directions contributes to turbulent flow, which assists in cleaning the electrode plates and improves reaction speed and efficiency.

In almost every situation, the area of the aperture in a group one plate is expected to be unequal to the sum of the areas of the plural apertures in a group two plate. Consequently, the process liquid will undergo changes in velocity as it moves from one treatment chamber to the next. These velocity changes further contribute to turbulent flow.

The configuration of the inner edges of the spacers and gaskets is designed to block stagnant areas or areas of relatively low flow rate, such that the flow rate cannot sustain a clean condition of the electrode surfaces. Empirical testing with circular peripheral apertures shows that the inner edge of the gasket should have an undulated shape, consisting of trough portions and crest portions. The inner edge of the gasket defines a recess or concave trough at each of the peripheral apertures of a group two plate. The trough or recess is centered along the outside edge of one of the peripheral

apertures. Thus, the number and positions of the troughs is equal to the number and positions of the peripheral apertures.

The contour of each trough portion tracks the outermost edge of a peripheral aperture up to about one-half the circumference of the aperture. The remaining half of an aperture's circumference is the innermost edge. This edge is open toward the center of the treatment chamber to allow process liquid to flow from the peripheral aperture of a group two plate toward the center aperture of a group one plate.

Neighboring trough portions of the undulated gasket edge are joined by a crest portion. Between troughs, the inner edge of the gasket defines a convex edge or crest centered on the central aperture of a group one plate. The apex of the convex edge typically will be spaced from the edge of the center aperture. A suitable spacing can be determined by the process of empirical testing. Often the crest will be separated from the central aperture by two or more diameters of the central aperture.

With reference to Fig. 1 of the drawings, a system 10 for treating a process liquid by electrocoagulation can employ a filter press style reaction chamber 12 using streamlined flow paths. On the upstream side of the chamber, the system can include a surge tank 14; a means for supplying chemical enhancement additives 16; and an ozone generator or oxygen source 18. On the downstream side of the chamber 12, the system can provide a development tank 19. In addition, the system is powered from a DC power supply 20 and controlled by a programmed processor such as a program logic controller (PLC) 22. In addition, the system may include supplemental standard equipment such as valves (V) and pumps (P) as required.

In a representative system, surge tank 14 holds a minimum of five minutes supply of process liquid, based on the applicable flow rate through the system. The surge tank contains a static mixer 24 for ensuring that any chemical additives 16 are thoroughly mixed with the process liquid. An ozone diffuser 26 or an oxygen micro-bubbler 28 are located near the bottom of the tank.

Chemical enhancement additives 16 commonly are acid or caustic solution for altering the pH of the process liquid. A metering pump 30 is controlled by a pH probe 32 in the surge tank for blending the acid or caustic chemical additives into the process liquid. Other additives can be added by a pump 34 controlled by a timer in the processor.

The ozone generator or oxygen source 18 is used to accelerate the oxidation rate of the electrolytic reaction. It also treats contaminants that may not be adequately treated in the reaction chamber. It is sized according to the flow rate of the system. Oxygen increases the overall oxidation rate of the electrolytic process. When ozone is used in place of oxygen, the rate of the overall oxidation reaction is increased by a factor of about thirteen. However, oxygen is less expensive and adequate for many applications.

With general reference to the Figs. 1-8 of the drawings, a reaction chamber 12 can be constructed of square electrode blades or plates 100 alternating between group one plates 36 and group two plates 38. The group one plates 36 have an aperture 40 at the center, while the group two plates have peripheral apertures, such as four apertures 42 distributed with one in each corner. The areas of the holes 40,42 are calculated to cause a pressure differential so that the velocity of the process liquid varies and causes turbulent flow as its passes between juxtaposed plates.

The plates are separated by spacers 46 formed of a chemically inert material such a polyvinylchloride. The spacers are selected for their predetermined thickness, which establishes a corresponding gap between the electrodes. A wide variety of spacer thickness can be preselected to accommodate the electrical requirements of the process liquid.

A gasket 48 is located between each plate and spacer for sealing the treatment chambers or zones 50 within the electrode stack. The gaskets and spacers are shaped by their inside edges to define streamlined flow paths in each treatment chamber 50. Gasket material typically is of a durometer in the range from sixty to seventy to produce a liquid tight seal without requiring adhesive. To a small degree, the gaskets influence the gap between electrodes. In addition, gaskets can be chosen with a preselected thickness to change the electrical characteristics of the reaction chamber.

The electrode stack is held in place by opposing pressure plates 52 located at opposite ends of the stack. The plates are equipped with fittings 54 for attaching inlet and outlet conduits to the chamber. The plates 52 are held together and compressed against the electrode stack by suitable compression rods that may include bolts, threaded rods, cam-locking fastener rods and the like. A set of four compression bolts 56 may connect the plates 52 at the four corners of the stack. In addition, another

compression means such as a cam-locking fastener 58 may interconnect the plates 52 at the midpoint of each straight side of the stack. The periphery of each electrode plate, gasket and spacer may be apertured to be threaded over the compression rods as an aid to the assembly of the electrode stack.

Each electrode plate 100 carries an electrically conductive ear 60 for receiving a DC electrical connection. The ears extend outside the gaskets on the outer surface of the electrode stack. A guard or cover can be placed over the reaction chamber to prevent inadvertent contact with the ears or any other electrified portion of the reaction chamber. As a safety measure, the guard may be equipped with an interlocking switch for shutting off power to the system when the guard is removed.

The development tank 19 receives treated process liquid under pressure from the reaction chamber 12. The treated liquid resides in tank 19 while floc forms. A static mixer 64 in tank 19 enhances floc development. A polymer injection system 66 can be used where polymers will improve the settling process.

The DC power supply 20 receives alternating current (AC) power from the grid and transforms it to DC through a rectifier. The positive and negative sides of the DC supply are selectively connected to electrode blades in the reaction chamber. The DC supply can switch or reverse polarity to the electrodes. Periodically reversing polarity minimizes any buildup of oxides on the electrodes.

Overall system control resides in the program logic controller 22. Controlled features include liquid flow rate, operation of pumps and valves, and application of power to the reaction chamber electrode plates.

In operation, the system 10 is suited to treat process liquids, which may include waste water, drinking water, or process water. Process liquid is pumped from a source 62 to the surge tank 14 at a specified number of gallons per minute. The surge tank provides flooded suction for a feed pump 68. It also receives chemical additives 16 such as acid or caustic solution to adjust the pH of the process liquid. The static mixer 24 blends the additives and the process liquid. Ozone or oxygen 18 are injected into the process liquid to enhance the normal rate of oxidation that will take place in the reaction chamber 12.

Optionally, polymers can be injected into the liquid in the surge tank to improve the floc structure of certain process streams. For example, when thickening

a stream of sewage sludge, five percent of the normal polymer rate improved the resulting solids from seventeen percent to over twenty percent.

The process liquid from the surge tank is pumped under pressure through a connection to one or more reaction chambers 12. Each reaction chamber contains electrode plates formed of selected metals to provide the optimum ions for the appropriate chemical treatment of the process liquid. If multiple reaction chambers 12 are connected to the surge tank, individual reaction chambers can be placed on-line or off-line by suitable valves 67. This allows adjustment for varying flow rates and permits maintenance of individual chambers while processing continues in another chamber. The power supply 20 provides DC current to the electrodes, where the electricity passes through the process liquid and causes chemical reactions tending to form impurities into precipitates and flocs.

The treated process liquid exits the reaction chamber and enters the development tank 19 while still under pressure. A residence time in the development tank allows floc to develop and be separated from the remaining portion of the treated process liquid, which often is clean water. Static mixer 64 in the development tank increases the rate of floc development and increases the efficiency of the polymer injection system 66. Liquid from the development tank can be pumped or gravity fed to a secondary separation system 69 such as a clarifier, filter press, filter, or the like.

Two systems clean the reaction chamber when it is inactive. One system 70 purges the chamber and then cleans it by pumping in acid or caustic solution that removes any build-up of contaminants on the electrode plates. A second system 72 purges the chamber with water to remove contaminants. The chamber is allowed to remain filled with clean water when it is idle. The water prevents oxidation on the electrodes.

According to one detailed embodiment of the reaction chamber, and with reference to Fig. 2, a square electrode plate 100 has equal sides 30.5 cm (12 in) in length. An electrical connection ear 60 extends from one of the sides at a position near one of the corners. The plate can be configured as either a group one or group two plate, according to the number and position of apertures formed in it. A central aperture 40 is formed through each group one plate. Four corner apertures 42 are formed through each group two plate. The corner apertures are spaced from the edge

of the plate by 13.5 mm (0.53 in). Each aperture 40,42 is 19 mm (0.75 in) in radius. With an electrode plate 45.7 cm (18 in) per side, the preferred aperture radius is 2.5 cm (1 in). In an electrode plate 61 cm (24 in) per side, the preferred aperture radius is 3.8 cm (1.5 in).

With reference to Fig. 3, a gasket 48 has a square outer edge 30.5 cm (12 in) per side and is sized to fit over the electrode plate with edges aligned. The inside edge of the gasket is contoured in an undulating pattern. At a position over the corner aperture of the electrode, the gasket is shaped with a trough or recess 102 having a concave curve on a 19 mm (0.75 in) radius. The concave curve is located on the gasket to align with the edge of a corner aperture 42 of a group two plate over approximately the outermost one-half of the circular aperture. In a gasket having 45.7 cm (18 in) side edges, the concave curve has a 2.5 cm (1 in) radius; or with a gasket having 61 cm (24 in) side edges, the curve has a 3.8 cm (1.5 in) radius, or in each case conforming to the radius of the aperture in a mating electrode plate.

The inner edge of the gasket forms a crest or convex curve 104 between concave curves 102. The apex or center point of the crest is spaced 5 cm (2 in) from the outer edge of the gasket. The end of the crest meeting the trough blends smoothly. In a gasket having 45.7 cm (18 in) side edges, the apex of the crest is 7.6 cm (3 in) from the outer edge; or with a gasket having 61 cm (24 in) side edges, the apex of the crest is 10 cm (4 in) from the outer edge. Gaskets typically will be 3.2 mm (0.125 in) in thickness.

Spacers 46 are shaped identically to gaskets 48 but vary in thickness. Suitable spacer thicknesses are 6.4 mm, 9.5 mm, 12.7 mm, 19 mm, and 25.4 mm (1.4 in, 3/8 in, 1/2 in, 3/4 in, and 1 in).

With reference to Fig. 4, the reaction chamber 12 is formed by a stack of electrode plates arranged between pressure plates 52 on opposite ends. Each electrode is juxtaposed to a gasket on each of its faces, and a spacer 46 is interposed between the gaskets associated with juxtaposed electrodes. In addition, an end gasket 48 and an end spacer 46 are interposed between each of the pressure plates and each end electrode. Elongated compression members 56 join the pressure plates and allow them to be drawn toward each other to compress the gaskets. With reference to Fig. 5, the assembled reaction chamber may include bolts or tightening rods 56 at each corner of

the pressure plates. Alternate compression members such as cam-locking rods 58 may be located at one or more locations intermediate the corners.

With reference to Fig. 6, the electrode plates in the stack are arranged with group one and group two plates in alternating positions, with the electrical connecting ears in alternating directions. This eases connection of one electrical pole, such as the positive pole, to every other plate, such as all of the group one plates. The opposite pole, such as the negative pole, is connected to all group two plates. The pressure plates 52 are provided with a fitting or connecting nipple 54 for an inlet or outlet to the reaction chamber.

With reference to Fig. 7, the flow path through the reaction chamber 12 is sinuous. Liquid entering the chamber through one end is directed sequentially through alternating electrodes of groups one and two, in whatever order is selected during assembly of the chamber. The liquid follows a flow path 106 that variously diverges and converges as its traverses each treatment zone, as defined between two juxtaposed electrode plates.

With reference to Fig. 8, the flow within each zone is represented by the arrows 106. This flow is turbulent due to the varying contour of the zone. The liquid changes velocity frequently. For example, in passing through the four apertures 42 of a group two plate, the liquid sees an overall large passageway represented by the areas of the four apertures. The liquid can flow relatively slowly through such a large portal. However, when subsequently passing through the single aperture 40 of the juxtaposed group one plate, the liquid sees a relatively small portal represented by the area of the single aperture. The liquid must flow relatively faster through the smaller portal. Additional velocity changes result as the liquid passes from the narrow portions of a single zone to a wider portion, or vice versa. This turbulent flow improves the efficiency of the electrocoagulation process and helps to clean the electrode surfaces of accumulated precipitates or floc.

Another preferred embodiment is shown in Figs. 9 and 10, in which a desirable reaction chamber 108 allows the number of blades or electrode plates in the electrode stack 109 to be varied. It also allows the electrode plates to be removed and reinstalled for cleaning or replacement in a simple and efficient manner. This chamber is constructed with a filter-press type of design using a frame 110 that

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Another preferred embodiment is shown in Figs. 9 and 10, in which a desirable reaction chamber 108 allows the number of blades or electrode plates in the electrode stack 109 to be varied. It also allows the electrode plates to be removed and reinstalled for cleaning or replacement in a simple and efficient manner. This chamber is constructed with a filter-press type of design using a frame 110 that

supports a pair of spaced apart, generally horizontal, longitudinal, dielectric rails 112. Typically a rail is constructed of metal and carries an electrically insulating wear strip or other dielectric covering 114 at all contact areas with an electrode plate. The rails are well suited to support easily fabricated, square electrode plates 101, 102, as shown in Figs. 13 and 14. The plates include laterally extending ears 116 that overlie the rails and support each plate on the rails by gravity. In addition, the ears 116 serve as supporting rail guides that allow the plates to be positioned by sliding on the rails. The rail guides 116 may have a recess or hooked shape opening to the bottom side for engaging a rail and sliding on the rail when pushed longitudinally.

The frame supports a pair of spaced apart pressure plates 118 that rest on rails 112 and serve as the opposing end plates for the intermediate electrode stack 109 of reaction chamber 108. A supporting ear or rail guide 116 extends from each lateral side of plates 118 in a suitable position for engaging the rails 112. One of the pressure plates 118 is a stationary end plate located at one longitudinal end of the rails 112, such as the right hand end in the view of Figs. 9 and 10. The stationary plate 118 is lodged against an end of frame 110, which supports the stationary plate against movement. A second pressure plate 118, at the left end of the reaction chamber in the view of Figs. 9 and 10, may be regarded as a moveable plate. The second plate 118 can be selectively pressed against the juxtaposed end of the electrode stack, pushing the stack against the stationary plate and, thus, sealing it. When pressure through the moveable plate is released, the electrode stack can be spread apart along the rails, and any component can be lifted from the dielectric rails, such as for maintenance or replacement.

With reference to Fig. 11, the external face of pressure plate 118 is configured to allow a central force on the plate to seal the electrode stack. A force dissipating pad 120 at the center of plate 118 provides a thickened contact area. A plurality of gussets 122 radiate from pad 120 and extend to the periphery of the plate. The plate may carry an inlet or outlet fitting 54. The pad and gusset structure prevents the plate from warping or deforming when a central pressure is applied on pad 120.

A compression means or device selectively pushes the moveable plate 118 against the electrode stack, sealing it against leakage and allowing pressurized operation. The compression device also selectively releases the pressure to allow

electrode plates 101,102 to be removed for maintenance or replacement. A preferred compression device is a fluid operated piston cylinder, operable between an extended position and a retracted position. A pneumatic or hydraulic powered cylinder 124 is suitable. The cylinder 124 acts between the left end of frame 110 and moveable plate 118 on the left side of the electrode stack in the view of Figs. 9 and 10. The hydraulic cylinder can work over a range of extension, allowing the number of electrode plates in the electrode stack to be varied. One end of the cylinder 124 may be connected to the frame 110, and the cylinder is positioned for the opposite end to contact the nearer end plate 118 when the cylinder is extended, to compress the electrode stack.

The electrode plates used in reaction chamber 108 provide turbulent flow of the process liquid, flowing through a flow path defined by alternating group one and group two plates. In this embodiment, the electrode plates include supporting rail guides 116 for carrying the electrode plates on the rails 112. Each pair of electrode plates is separated by a spacer that also includes rail guides 116. Fig. 12 shows a modified spacer 103 defining a central spacer opening, preferably with a round edge profile defining a circular opening of predetermined diameter. The spacer may carry a compressible seal at each face. Thus, both faces of the spacer 103 may define a retaining groove that carries an O-ring seal 117 juxtaposed to the edge of the central opening. The O-ring seal on each face of the spacer substitutes for a gasket 48. The spacer is formed of a dielectric material. The thickness of a spacer can be selected to establish a desired spacing between blades.

A single treatment chamber may be regarded as including a central spacer with a group one plate on one face and a group two plate on the opposite face. As shown in Fig. 14, the group one plate 101 defines a central aperture 40, preferably round, that is smaller than the central spacer opening. The diameter of aperture 40 preferably is about twenty percent or less of the diameter of the central spacer opening. Plate 101 includes lateral rail guides 116 capable of supporting the plate 101 from rails 112. The plate may include an electrical connecting ear allowing connection to an electric power source 20, although one of the rail guides 116 may be adapted to serve this additional function. Preferably, the rail guide serving as a connecting ear is provided

with an attachment point such as hole 126 suited for connection to an electrical connecting lug and wire pigtail 128.

A modified group two electrode plate 102 is used on the opposite side of the spacer. As shown in Fig. 13, the modified plate 102 has peripheral apertures 104 configured as arcs of a peripheral circular slot. The outer edge of the arcuate apertures lies closely within the diameter of the O-ring seal 126 so that the slot is radially juxtaposed to the central spacer opening. A minimal peripheral area of plate 102 is exposed to process liquid outside the position of slot 104 to abate fouling. The slot 104 is discontinuous as necessary to support the central portion of plate 102. For example, the central, disk-shaped portion may be connected to the peripheral portion of the plate at one or more connecting areas. The connections should be as narrow as practical, with the typical arc of such a connection being about fifteen degrees. Thus, if four connecting areas are used, as shown in Fig. 13, the slot 104 will extend over about three hundred degrees, and the connecting areas will extend over about sixty degrees. The electrode plate 102 includes a connecting ear or lug attachment point 126 as previously described.

The cumulative area of apertures 104 is smaller than the size of the central spacer opening but larger than size of the opening 40 in plate 101. For example, the height or radial dimension of the arcuate slot can be about 13 mm (0.5 in) relative to a diameter of about 25.4 cm (10 in) for the central spacer opening. Process liquid is maintained in turbulent flow along the flow path passing through the differently sized openings 40 and 104. The turbulence is encouraged by the non-linear flow path and by differing areas of the apertures in juxtaposed plates.

Electrical power is easily applied or removed from the plates of the reaction chamber 108. In one desirable arrangement, plates 101 may be arranged on dielectric rails 112 with the connecting points 126 all on one side of the chamber, while plates 102 are arranged with point 126 on the opposite side of the chamber. Positive connections may be applied to one side, while negative connections are applied to the other. Lugs and wire pigtails 128 may carry waterproof twist plugs, often referred to as CAM connectors, that allow rapid connection or disconnection of each plate from the DC power supply 20.

The operation of the reaction chamber in Figs. 9 and 10 is streamlined and requires a minimum of maintenance labor. The reaction chamber is assembled by setting in place a desired sequence of spacers, group one plates, and group two plates on the dielectric rails 112 between the opposite end plates 118. Typically a spacer is juxtaposed to each end plate. A series of reaction zones is established, starting at one end, by adding a plate selected from one of the two groups, followed by another spacer, followed by a plate from the other group. The connecting points 126 of the two groups of plates should be positioned in a sensible way for the planned polarity of each blade, such as respectively right and left. The sequence is repeated as desired within the available length of the rails, terminating at the spacer juxtaposed to the opposite end plate.

When the hydraulic cylinder 124 is applied to compress the electrode stack, the plates and spacers move together by sliding on the rails. The stack is self-aligning. The O-ring seals produce a pressure-tight reaction chamber, enabling the process liquid to be pumped into or out of the chamber. Electricity can be connected to the plates via the pigtails either before or after the stack is compressed. Numerous patterns of electrical connection are possible. For example, power can be applied to first and last blades, or the electrode stack can be subdivided into multiple chambers. Regardless of what connection scheme is used, an advantage of reaction chamber 108 is that all electrical wiring is external of the flow path and protected by the pressurized nature of the chamber from exposure to liquid. A protective cover is applied over the electrode stack, extending at least as low as the rail guides. The wiring harness is housed above the electrical connections of the blades so that it can remain dry even when the electrode stack is opened.

The flow of process liquid through the reaction chamber will follow the flow path established by the chosen sequence of plates and spacers. Inlet and outlet fittings 54 are provided through the end plates 118. The fitting 54 serving as the inlet may contain a mixing tube to create initial turbulence in the process liquid. This turbulence is maintained by the sinuous flow path and changing velocities required by offset positions and varying sizes of the passages through plates 101 and 102.

Opening the electrode stack for cleaning is equally streamlined. The hydraulic cylinder is withdrawn, whereupon the moveable end plate, spacers, and electrode

plates can be spread freely on the rails. A catch pan 130 can be carried on the frame 110 below the rails to catch residual liquid from the opened chamber. This pan may be connected through a valve and hose to a drain, or captured liquid may be returned to the untreated process liquid.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be regarded as falling within the scope of the invention as defined by the claims that follow.

CLAIMS

1. An electrocoagulation reaction chamber for the electrolytic treatment of a stream of process liquid, comprising:

a supporting frame providing a pair of laterally spaced, longitudinally extending, dielectric rails for supporting an electrode stack;

first and second spaced apart end plates that are carried by said supporting frame;

an electrode stack that is located between said end plates and that defines a flow path therethrough for process liquid, formed of at least:

a dielectric spacer that is supported on said rails and which defines a central spacer opening that forms a portion of the flow path;

first and second electrode plates that are supported on the rails, wherein said first electrode plate is positioned between the first end plate and said spacer, and said second electrode plate is positioned between the second end plate and the spacer; and

wherein one of said electrode plates defines a central electrode aperture that is positioned centrally relative to the central spacer opening and forms a portion of the flow path; and the other of the electrode plates defines a peripheral electrode aperture that is positioned peripherally relative to the central spacer opening and forms a portion of a flow path;

a compression means for selectively applying or releasing a compressive force on the end plates for selectively applying compression to said electrode stack or releasing compression from the electrode stack;

an inlet means for supplying process liquid into a first end of the flow path; and

an outlet means for discharging process liquid from a second end of the flow path.

2. The electrocoagulation chamber of Claim 1, further comprising a means for supporting said first end plate on said rails for sliding movement.

3. The electrocoagulation chamber of Claim 2, wherein said compression means is applied against said first end plate for sliding the first end plate on said rails and against said electrode stack.

4. The electrocoagulation chamber of Claim 1, wherein said second end plate and frame are suitably arranged such that the frame braces the second end plate against movement away from said electrode stack.

5. The electrocoagulation chamber of Claim 1, wherein said dielectric spacer is supported on said rails by a means for allowing the spacer to slide longitudinally with respect to the rails.

6. The electrocoagulation chamber of Claim 1, wherein said electrode plates are supported on said rails by a means for allowing the plates to slide longitudinally with respect to the rails.

7. The electrocoagulation chamber of Claim 1, wherein said peripheral electrode aperture is juxtaposed to an edge of said central spacer opening.

8. The electrocoagulation chamber of Claim 7, wherein said edge of the central spacer opening is concave to said peripheral electrode aperture.

9. The electrocoagulation chamber of Claim 1, wherein said peripheral electrode aperture is arcuate.

10. The electrocoagulation chamber of Claim 9, wherein said peripheral electrode aperture is radially juxtaposed to said central spacer opening.

11. The electrocoagulation chamber of Claim 9, further comprising:

a compressible seal located between said spacer and each of said first and second electrode plates for forming a pressurizable electrode stack when longitudinal compressive force is applied to said first and second end plates.

12. The electrocoagulation chamber of Claim 1, wherein said peripheral electrode aperture smaller in area than said central spacer opening.

13. The electrocoagulation chamber of Claim 1, further comprising:

an electrical connection ear extending laterally of said first electrode plate;

a waterproof, selectively connectable and disconnectable wire connector joined to said connection ear; and

a DC power source connected at one pole to said waterproof wire connector.

14. The electrocoagulation chamber of Claim 1, further comprising:

a plurality of said first electrode plates, each having an electrical connection ear extending laterally; and

a plurality of said second electrode plates, each having an electrical connection ear extending laterally;

wherein the first electrode plates are arranged with said electrical connection ears extending to a first lateral side of the electrode stack; and

the second electrode plates are arranged with the electrical connection ears extending to a second lateral side of the electrode stack.

15. The electrocoagulation chamber of Claim 1, further comprising:

a catch tray carried by said frame below the electrode stack for catching process liquid when said compression means selectively releases compressive force on the electrode stack.

16. The electrocoagulation chamber of Claim 1, wherein said compression means comprises a fluid operated piston cylinder operable between an extended position and a retracted position, connected at one end to said frame and suitably positioned to push against said first end plate when in extended position.

17. A electrocoagulation reaction chamber for the electrolytic treatment of a stream of process liquid, comprising:

a supporting frame providing a pair of laterally spaced, longitudinally extending, substantially horizontally disposed dielectric rails for supporting an electrode stack;

first and second end plates carried by said supporting frame, wherein at least one of said end plates is slidably supported on said rails;

an electrode stack intermediate said first and second end plates, defining a flow path therethrough for process liquid, including:

a dielectric spacer supported on said rails and providing a central circular opening defining a portion of a flow path for process liquid;

first and second electrode plates supported on said rails, wherein said first electrode plate is positioned between said first end plate and said spacer, and said second electrode plate is positioned between said second end plate and the spacer; and

wherein one of said first and second electrode plates defines a circular central electrode aperture forming a portion of a flow path for process liquid, positioned centrally relative to said circular spacer opening and of smaller size than the circular spacer opening; and the other of the first and second electrode plates defines a plurality of peripheral electrode apertures forming a portion of a flow path for process liquid, positioned peripherally relative to the central spacer opening, and cumulatively of smaller size than the circular spacer opening;

means selectively applying and releasing a longitudinal compressive force to said first and second end plates for selectively compressing said electrode stack and releasing compression on the electrode stack;

an inlet means for supplying the process liquid into a first longitudinal end of the flow path; and

an outlet means for removing the process liquid from an opposite longitudinal end of the flow path.

18. A method of assembling an electrocoagulation chamber, comprising:

first, providing a pair of laterally spaced, longitudinally extending, generally horizontal, dielectric rails;

second, building an electrode stack on the dielectric rails by placing a sequence of alternating electrode plates and dielectric spacers on the rails, together with a pressure resistant end plate at each end of the electrode stack, wherein said electrode plates, spacers, and at least one of the end plates rest on the rails by gravity and are longitudinally slidable thereon;

third, compressing the electrode stack to seal the junction between each electrode plate and spacer.

ABSTRACT

Dielectric rails (112) support an electrode stack (109) that is compressed between end pressure plates (118). The stack is composed of a dielectric spacer (46, 103) forming a central spacer opening, separating a pair of electrode plates (101,102) that each have a different configuration of openings. A first electrode plate (101) of the pair has a central aperture, while the second electrode plate (102) of the pair has peripheral apertures. A compression device such as a hydraulic cylinder (124) compresses the stack, sliding the plates and spacers together to form a pressure-tight reaction chamber (108). When the cylinder is released, any plate or spacer is readily removed from the stack for replacement or maintenance merely by lifting it off the rails. An electric potential can be applied to each electrode plate at a connecting ear (116), which may be a one of the rail guides (116).

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	GIL 1012
First Named Inventor	GILMORE, F. William
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Art Unit	
Examiner Name	

As the below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original and first inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ELECTROCOAGULATION REACTION CHAMBER AND METHOD

(Title of the Invention)

the specification of which

☑ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ____ as United States Application Number or PCT International

Application Number ____ and was amended on (MM/DD/YYYY) ____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

PTO/SB/01 (10-01)
Approved for use through 10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

DECLARATION — Utility or Design Patent Application

Direct all correspondence to: ☑ Customer Number or Bar Code Label 26092 PATENT TRADEMARK OFFICE OR ☐ Correspondence address below

Name

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR : ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any]): F. William	Family Name or Surname: GILMORE
Inventor's Signature: F. William Gilmore	Date: 10/10/2002

Residence: City: Castle Rock	State: CO	Country: USA	Citizenship: US

Mailing Address: 1433 Pine Ridge Lane

City: Castle Rock	State: CO	ZIP: 80104	Country: USA

NAME OF SECOND INVENTOR: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Inventor's Signature	Date

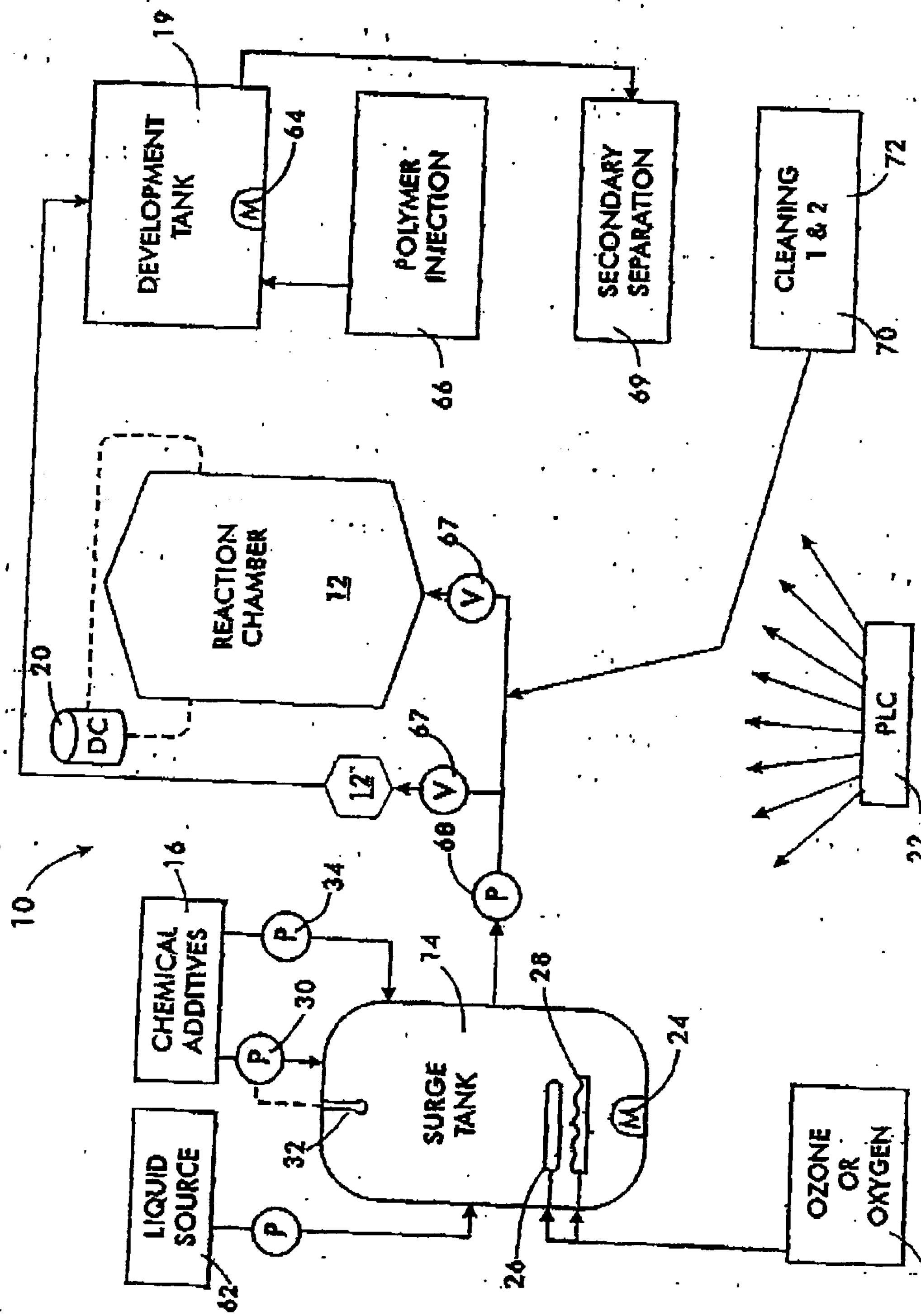
Residence: City	State	Country	Citizenship

Mailing Address

City	State	ZIP	Country

☐ Additional inventors are being named on the ____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

1/11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DC
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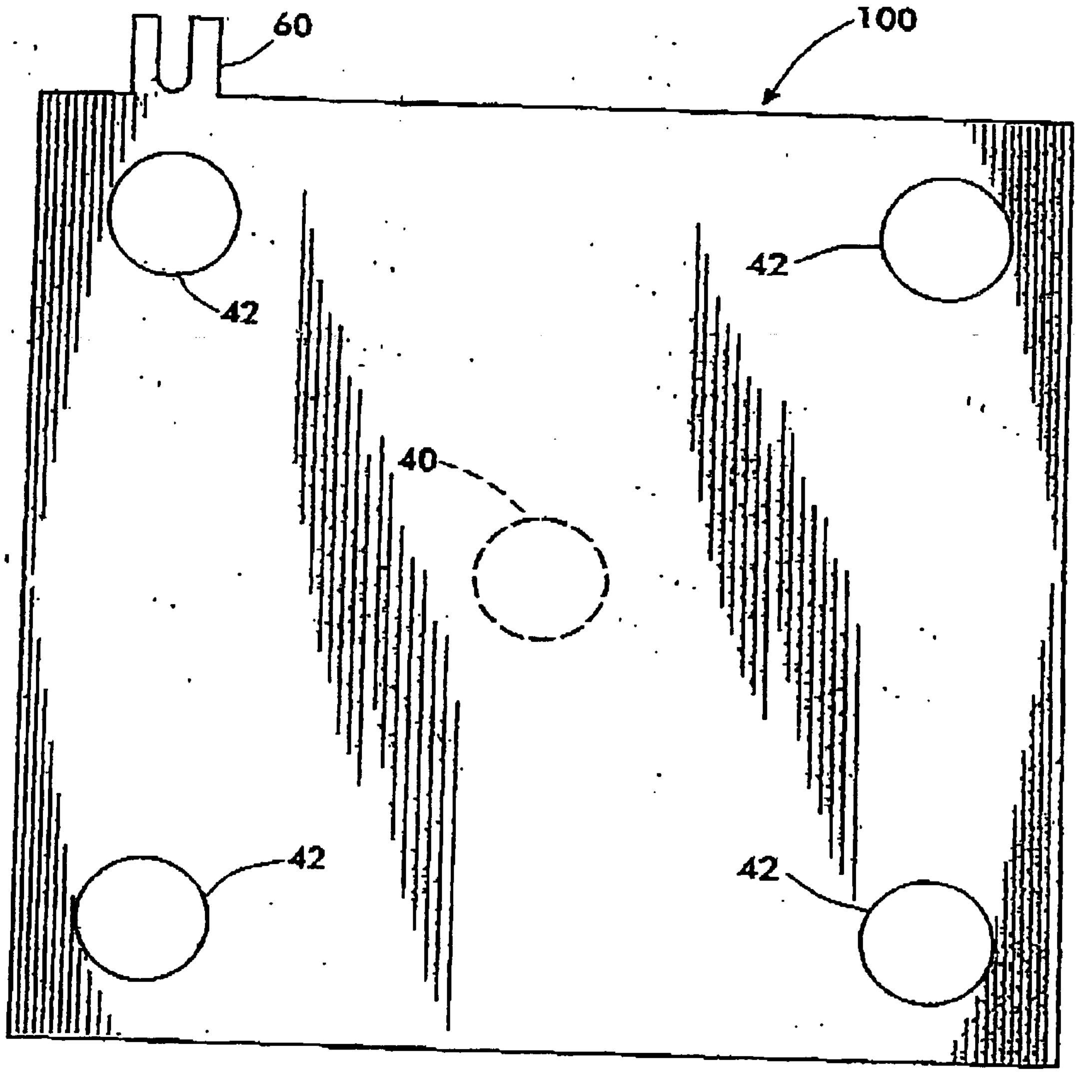
Fig. 1



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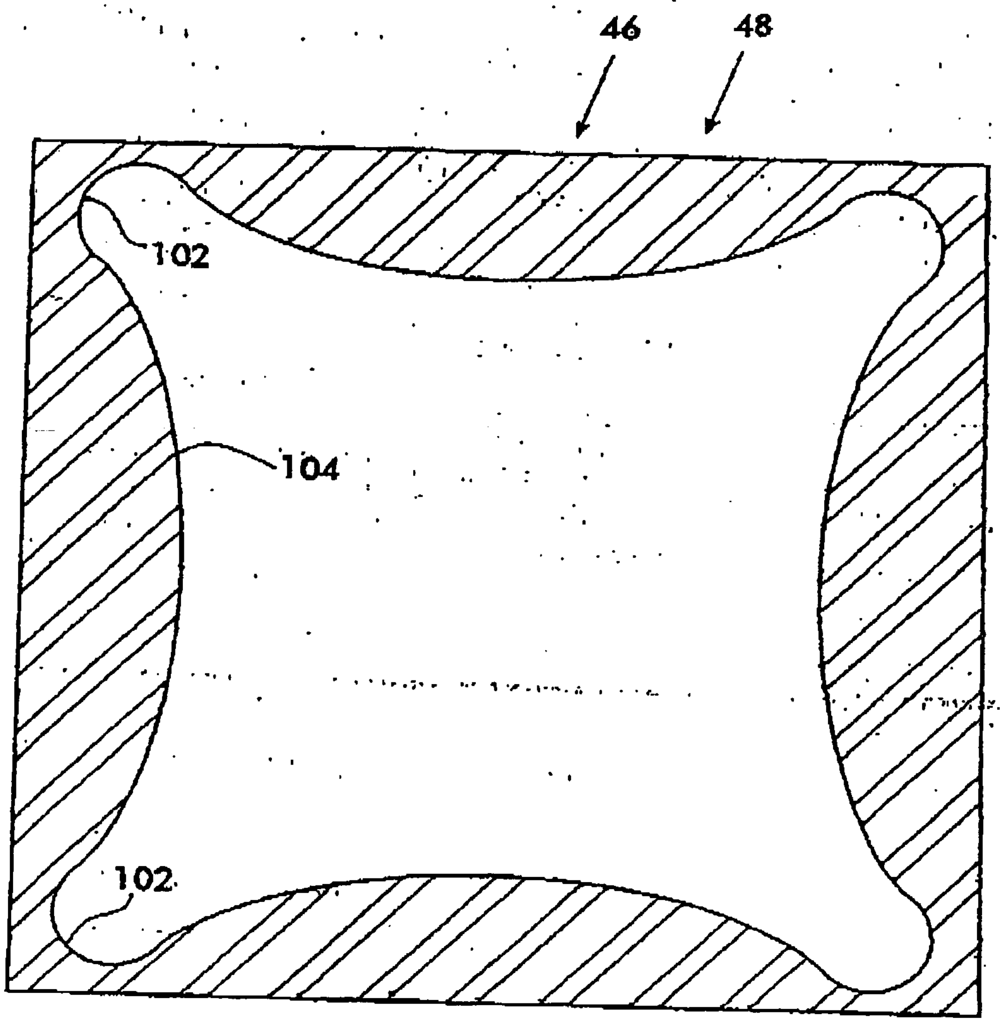
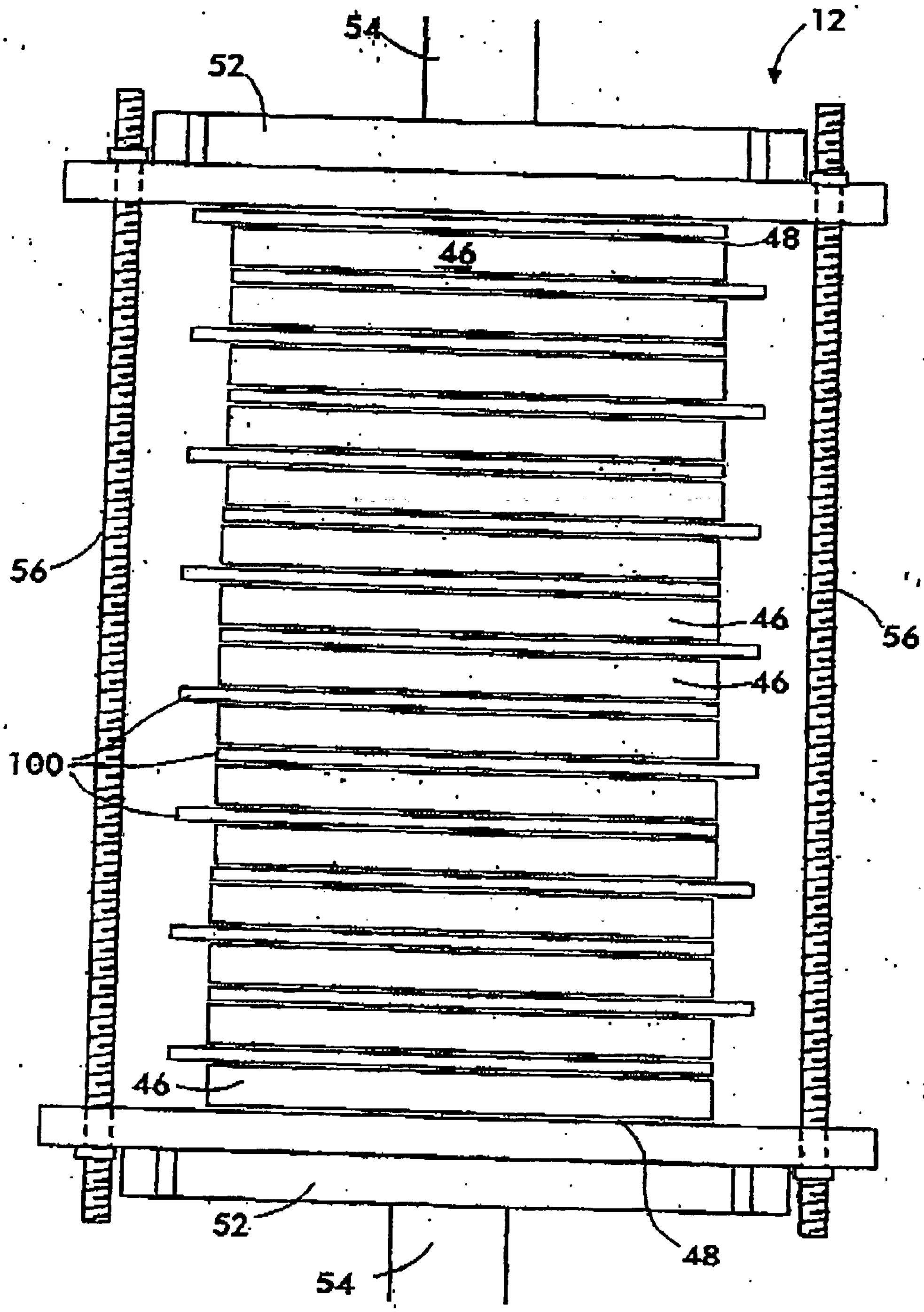


Fig. 3

4/11



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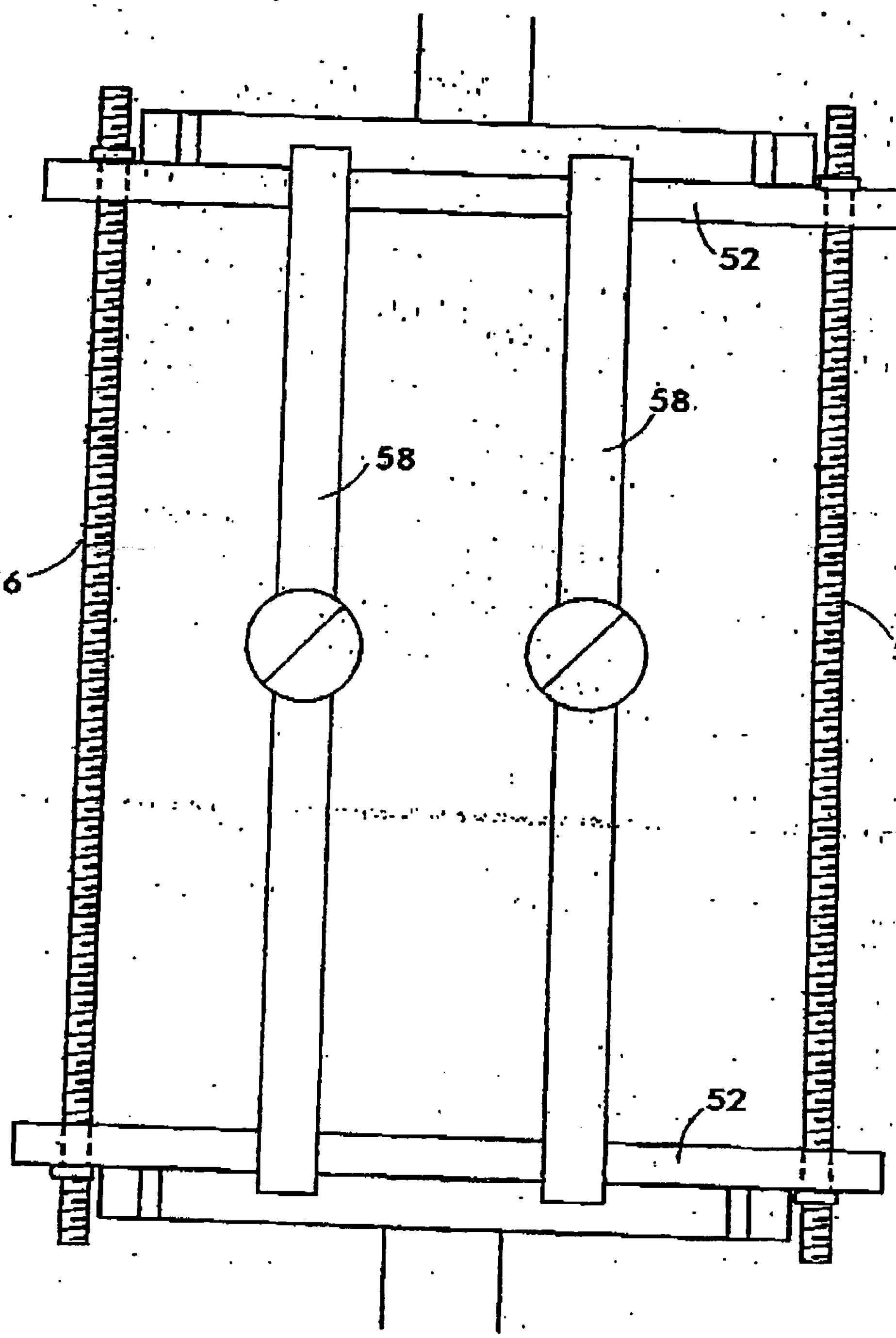

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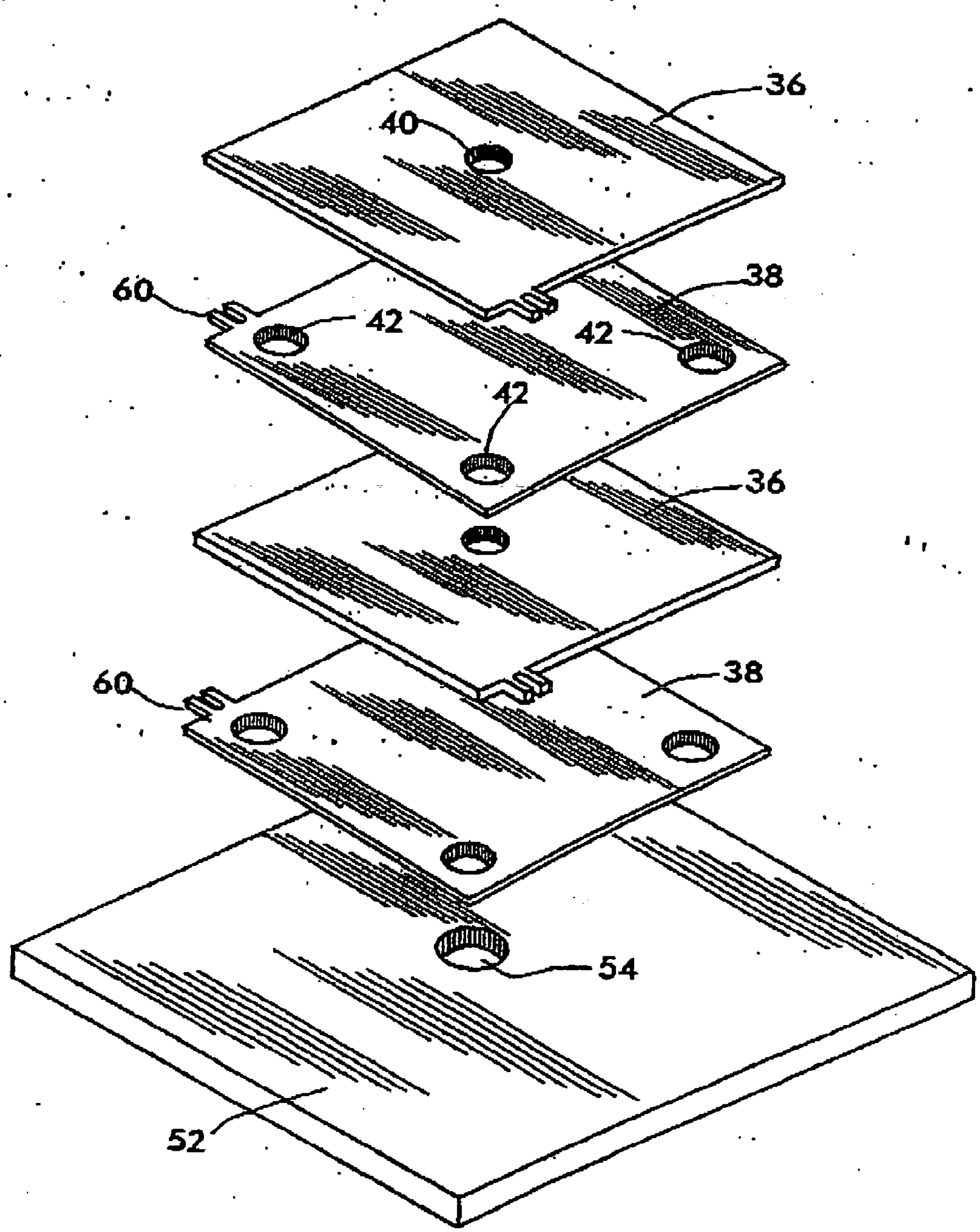

Fig. 6

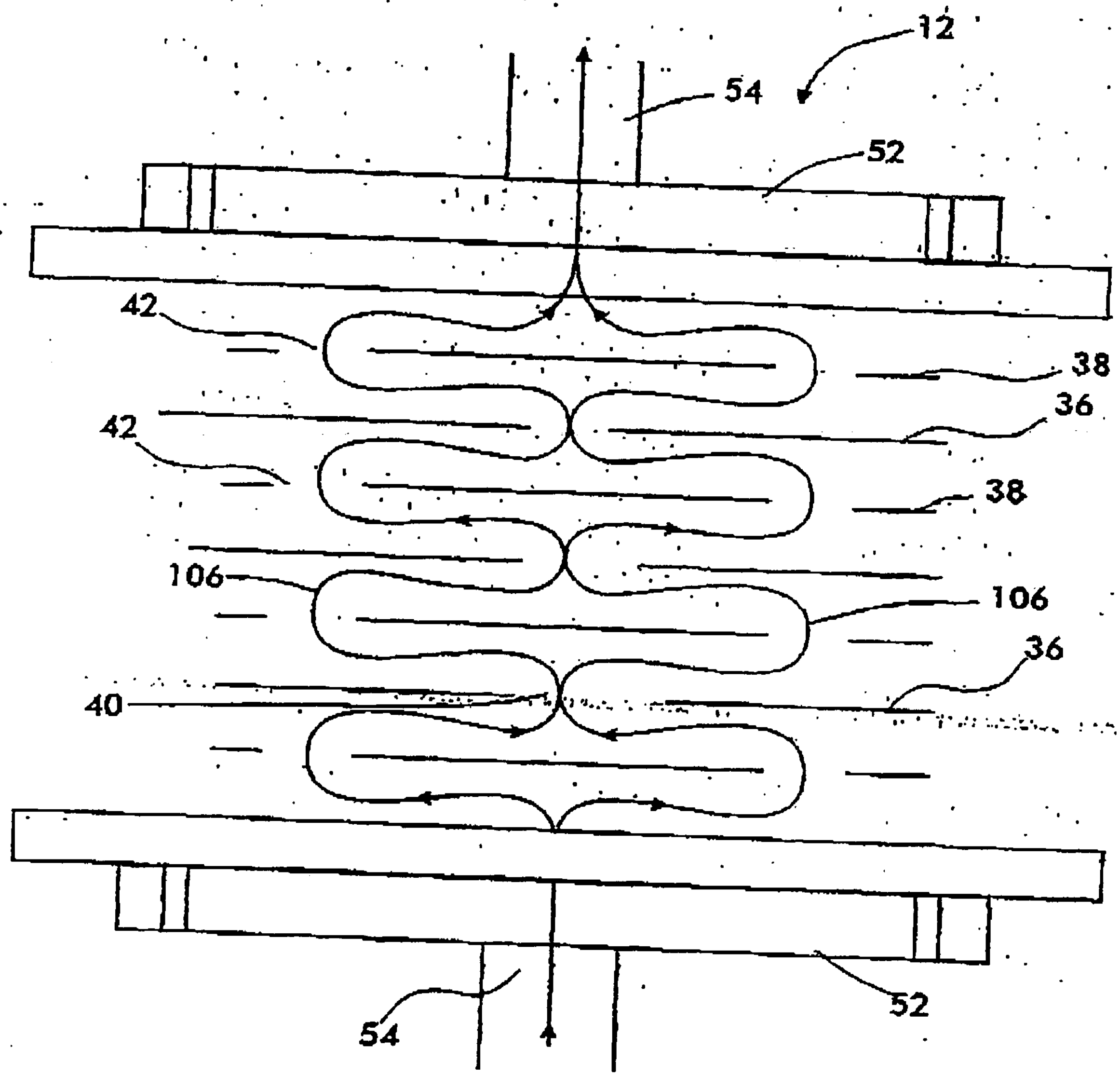

Fig. 7

8/11

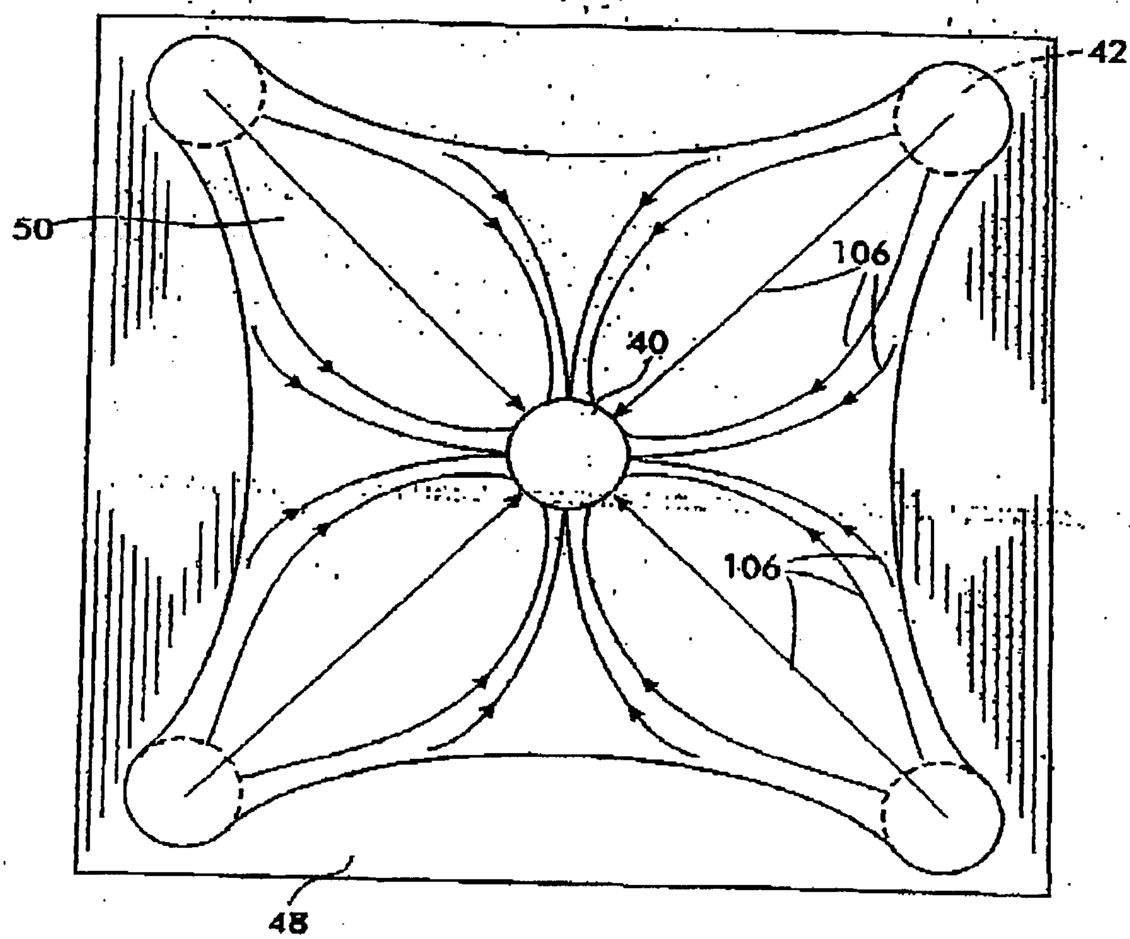

Fig. 8

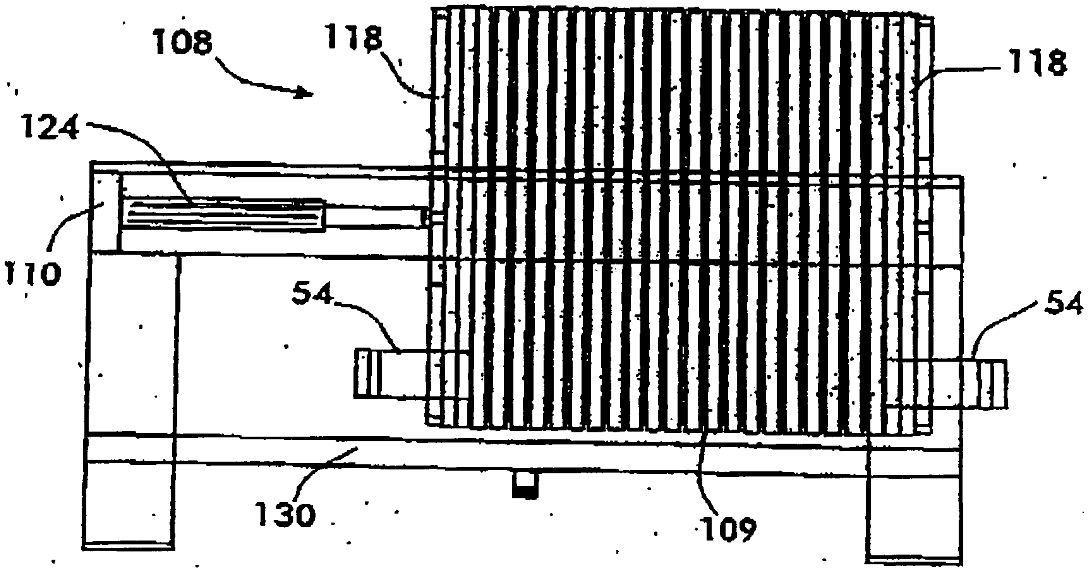

Fig. 9

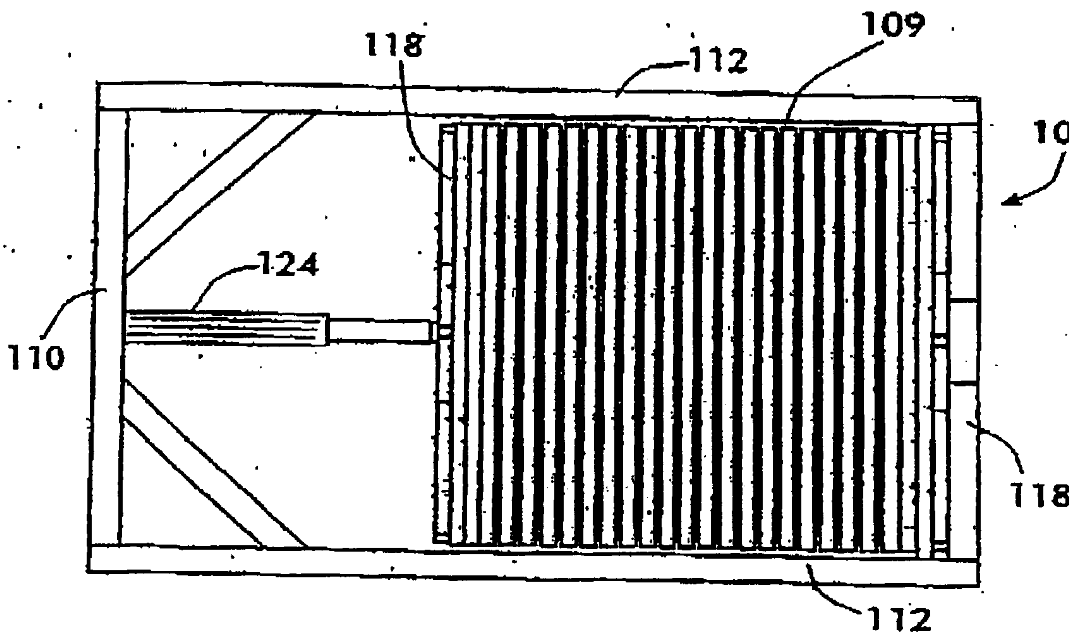

Fig. 10

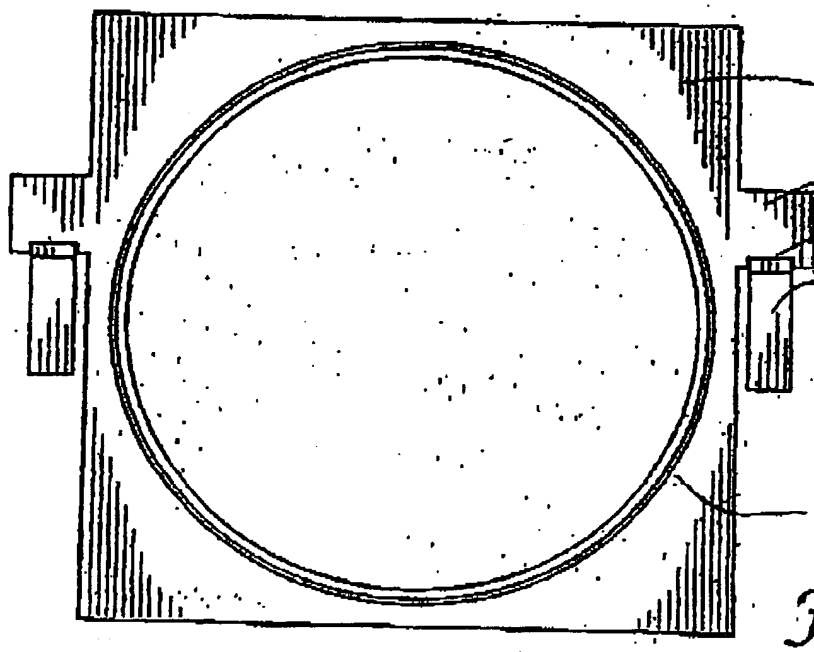

Fig. 11

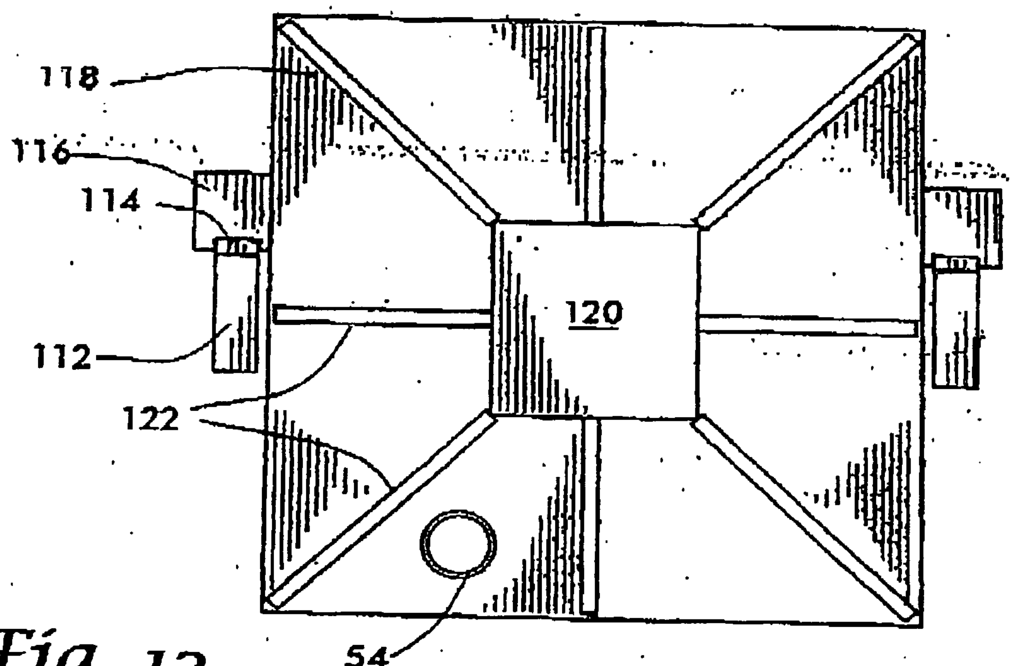

Fig. 12

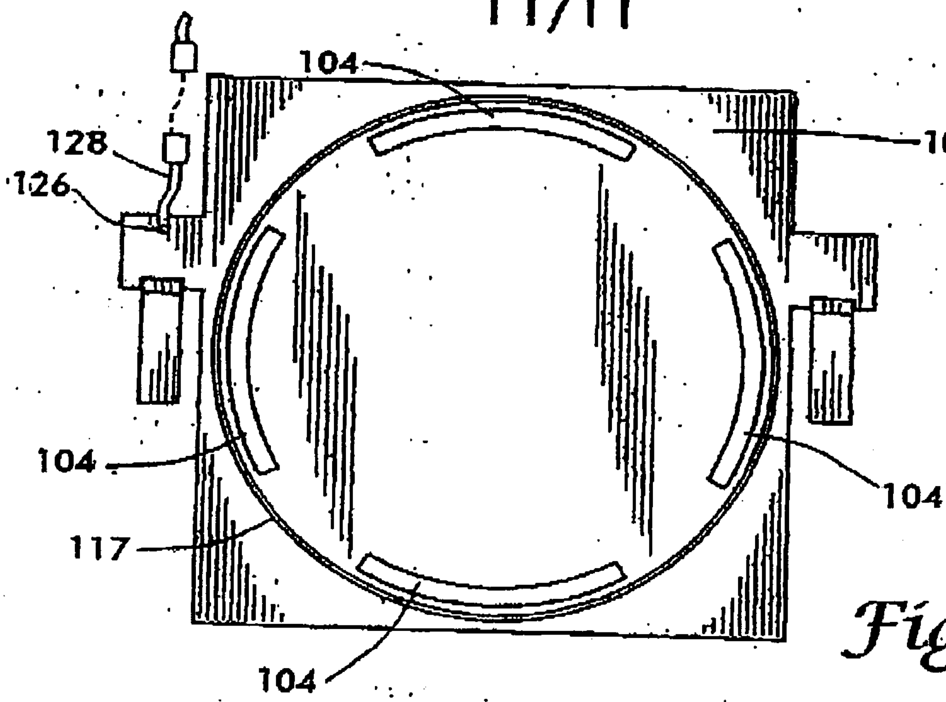

Fig. 13

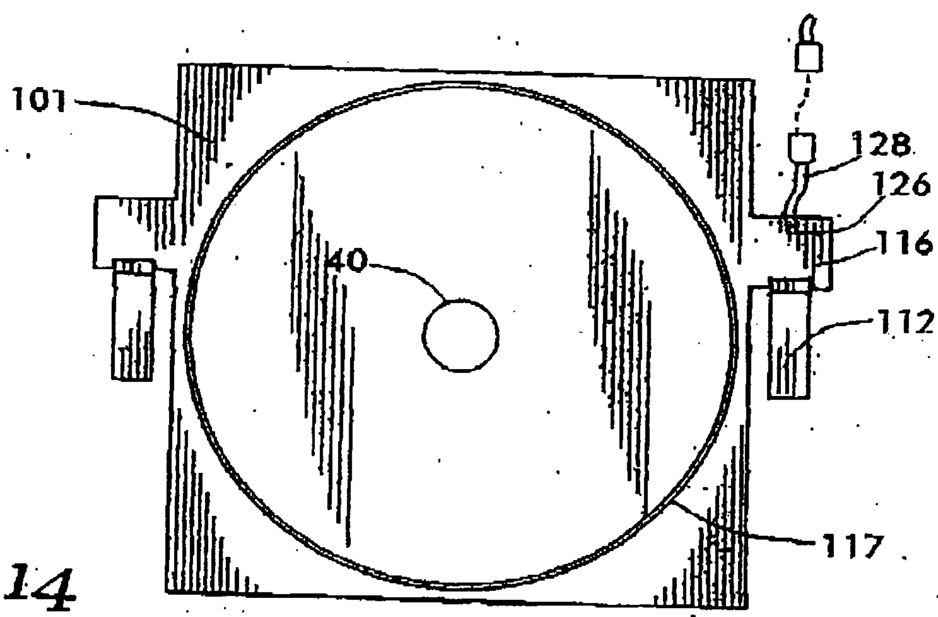

Fig. 14

Lindquist, Terrie

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Sent: Friday, September 20, 2002 4:21 PM
To: ROWAKA
Subject: Fax from '2813395400' (9 pages)

Attachments: M004EDB3.TIF

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ECOLOTRON, INC.
WATER RECOVERY SYSTEMS

FAX COVER LETTER

TO: Kent Rowald
COMPANY: Brace Patt
FAX: 713-222-3289
ph: 713-223-2900

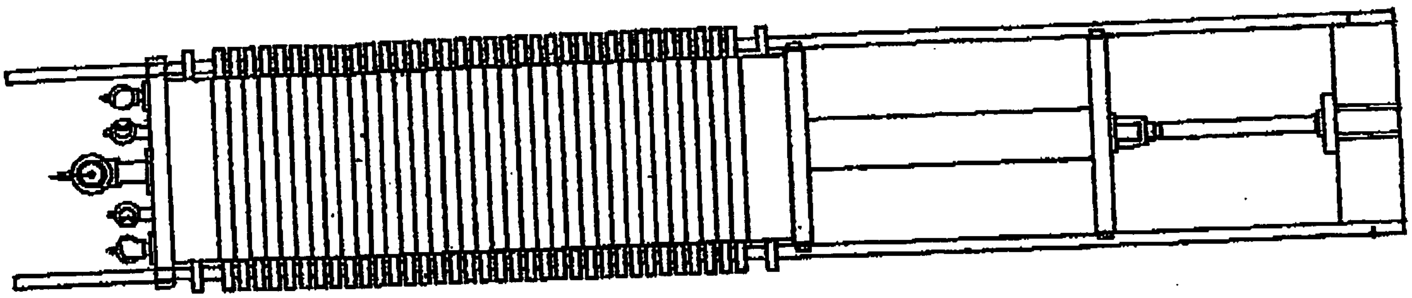
FROM: Gus Gavrel
DATE: 9/20/02
FAX: 281-559-1121

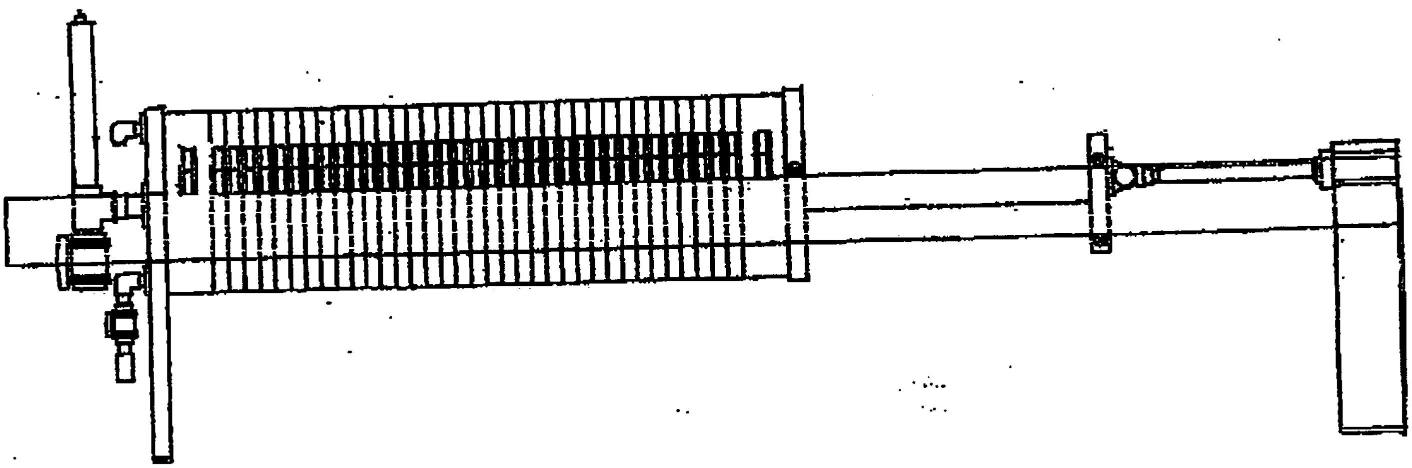
PAGES TO FOLLOW: 8

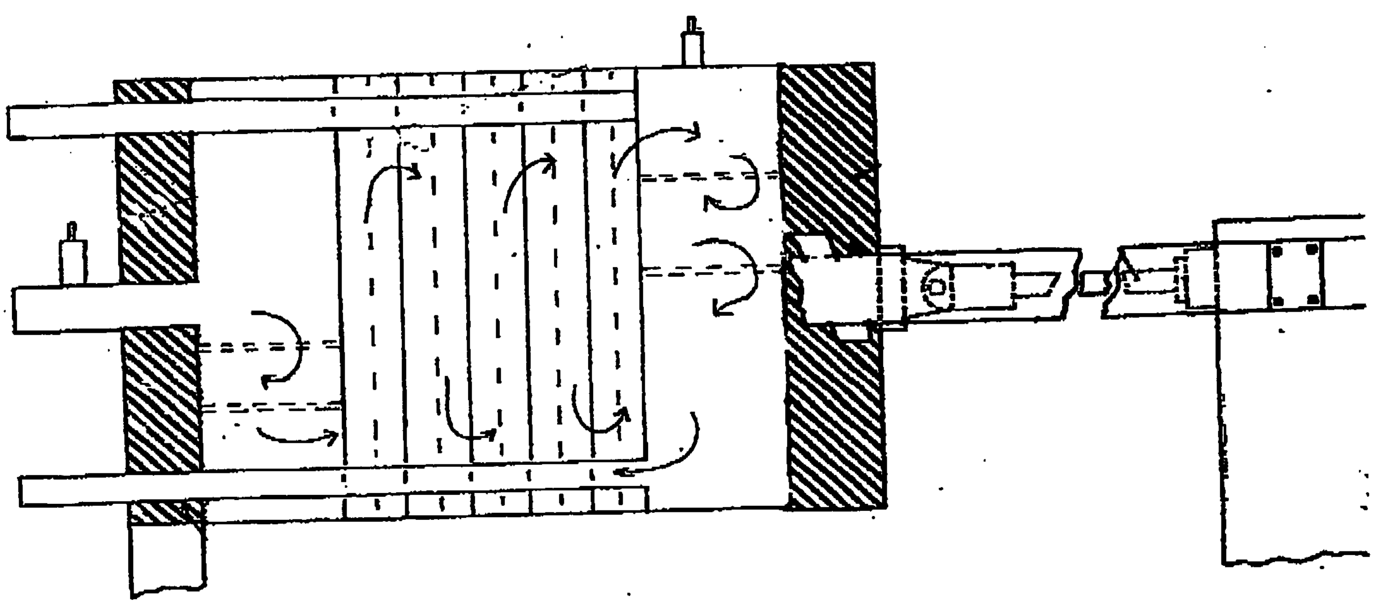
COMMENTS:
Could not e-mail, Too much data. Please find attached 8 dwgs. Text sent via e-mail. Much more To follow as completed.

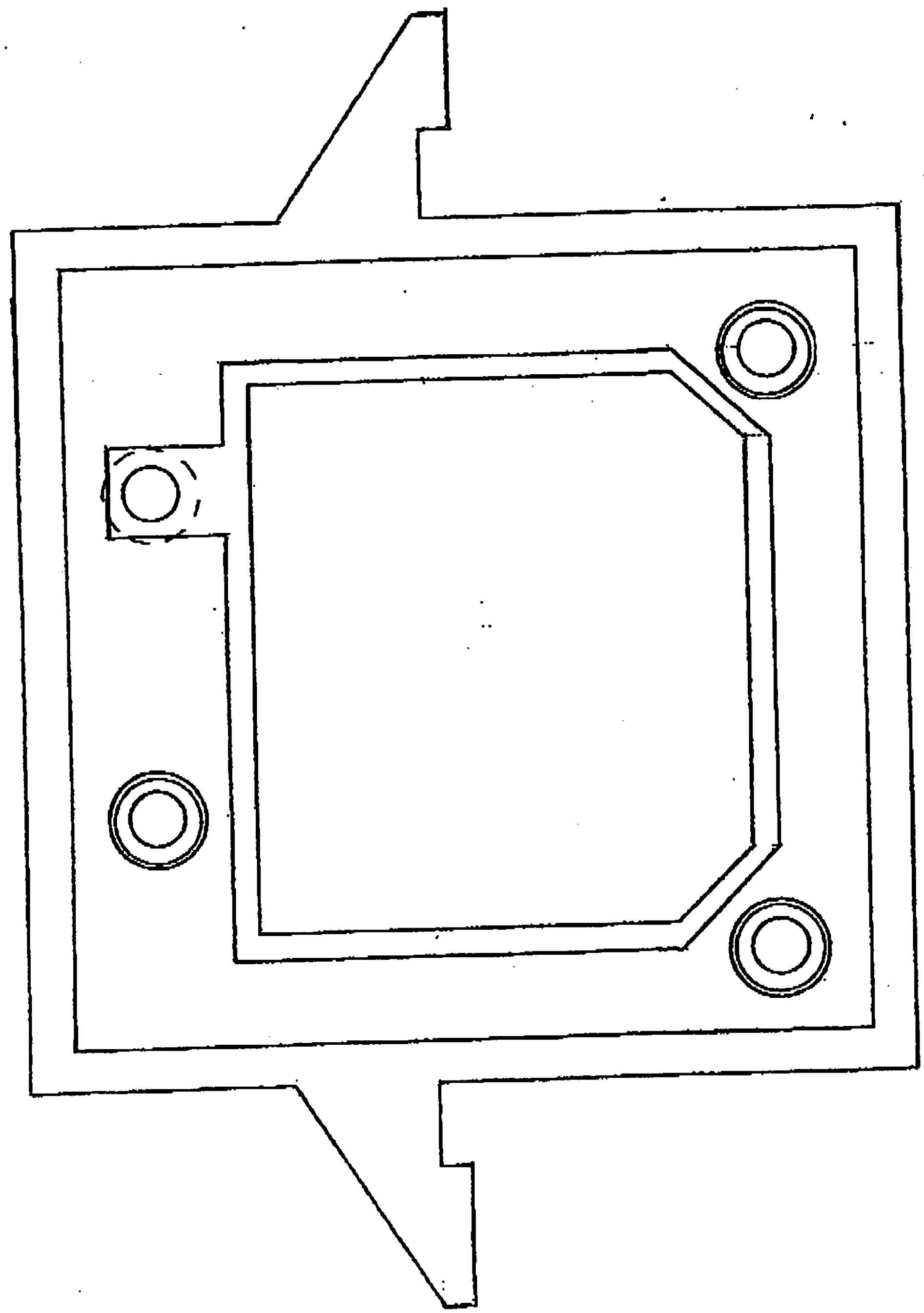
Thank you:
Tom Gus Gavrel

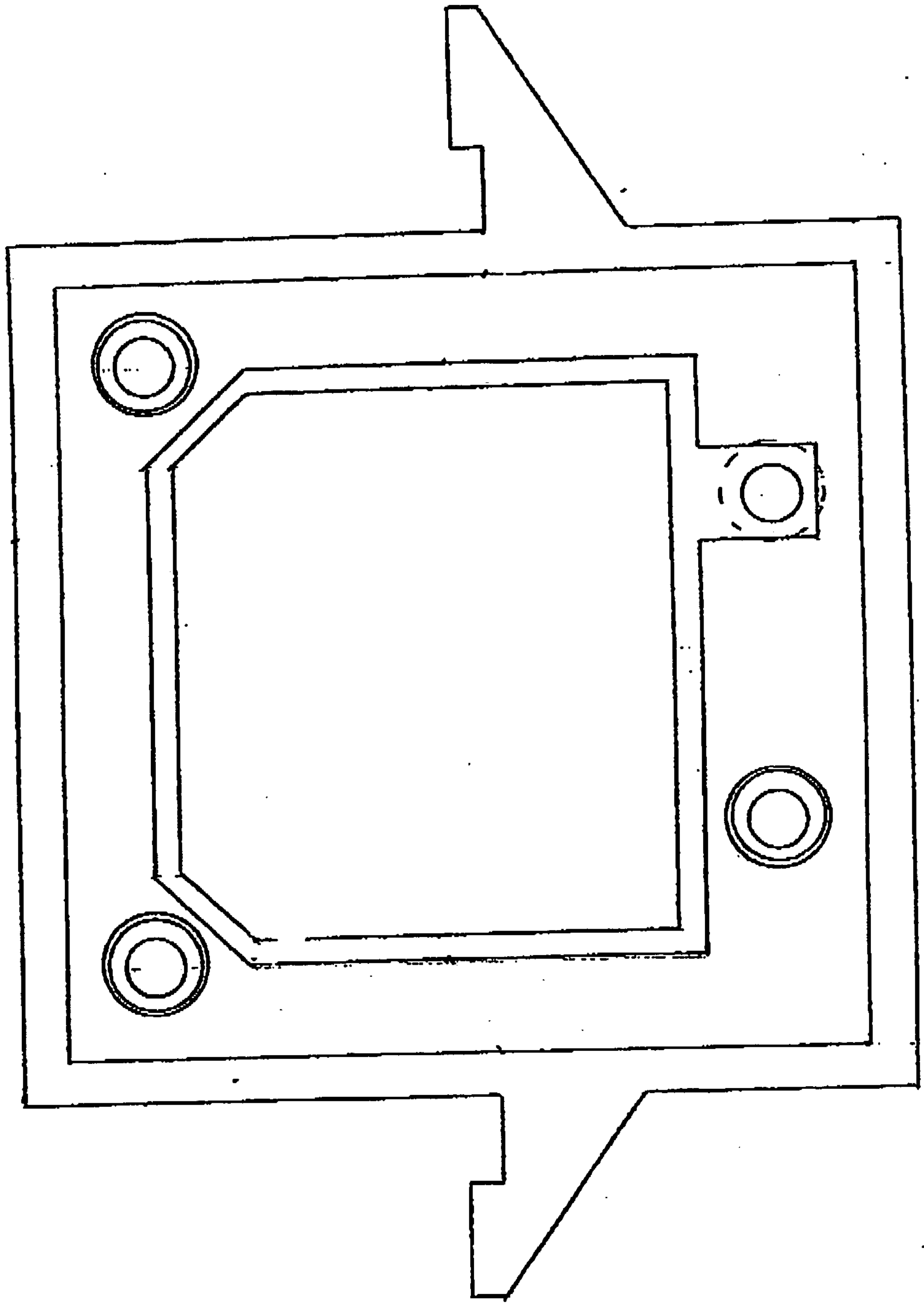
Confidentiality Statement

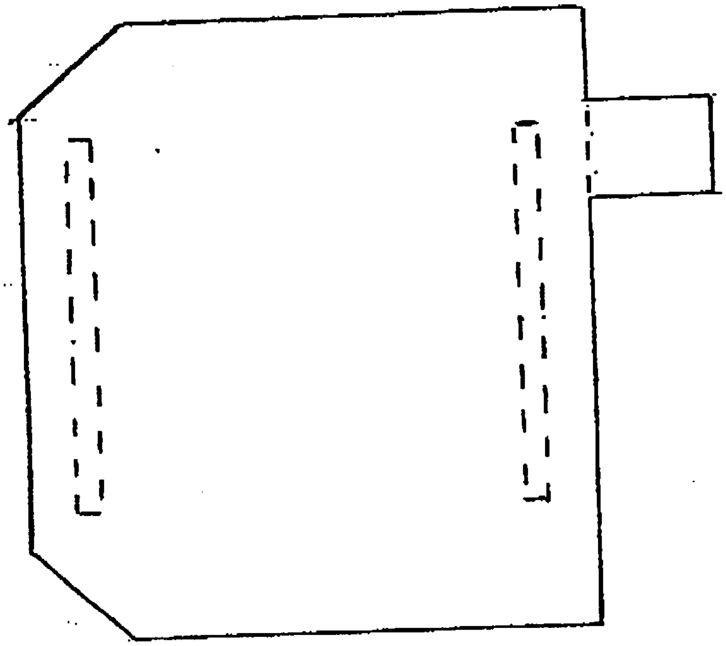


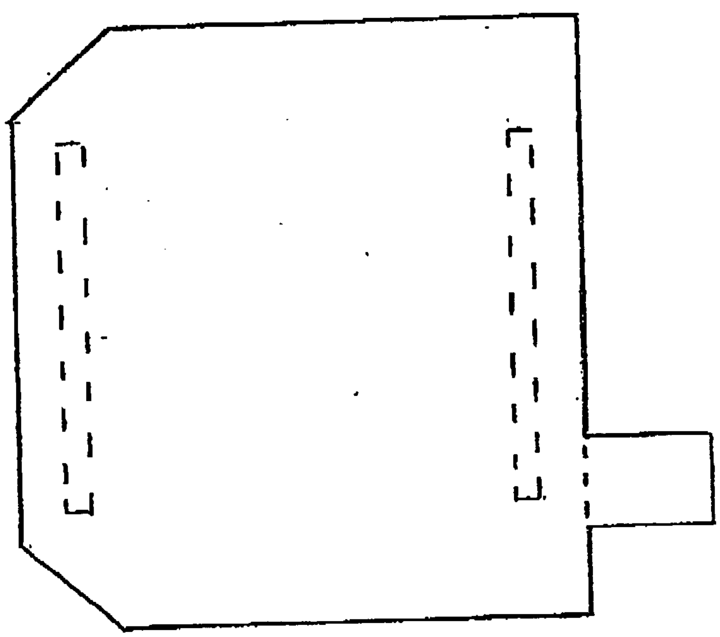


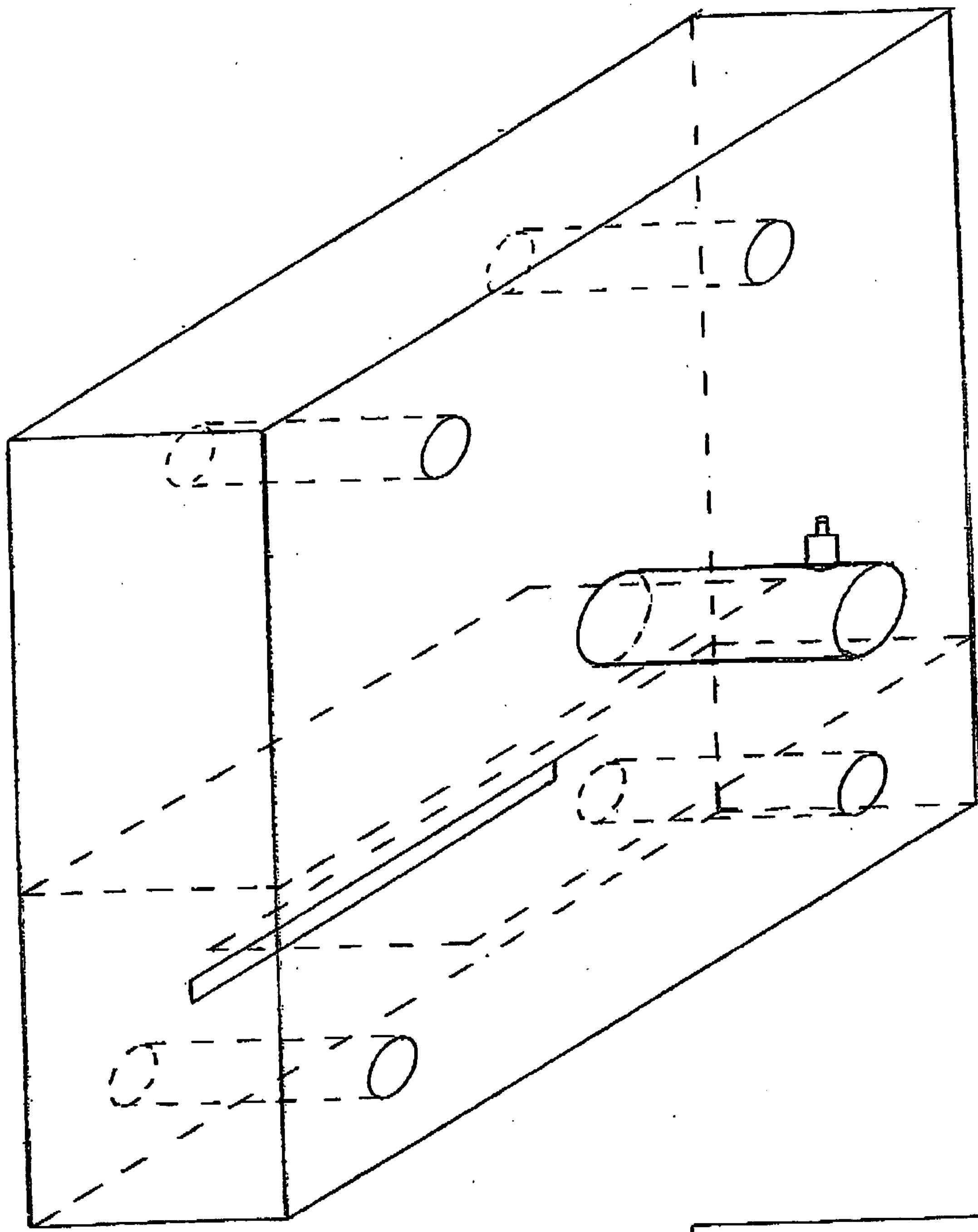


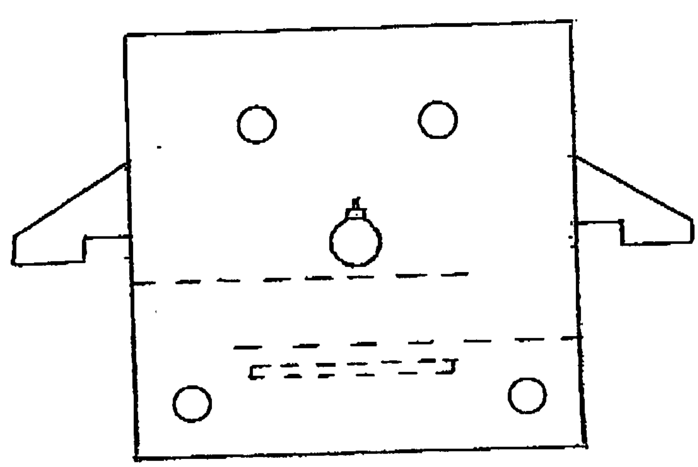


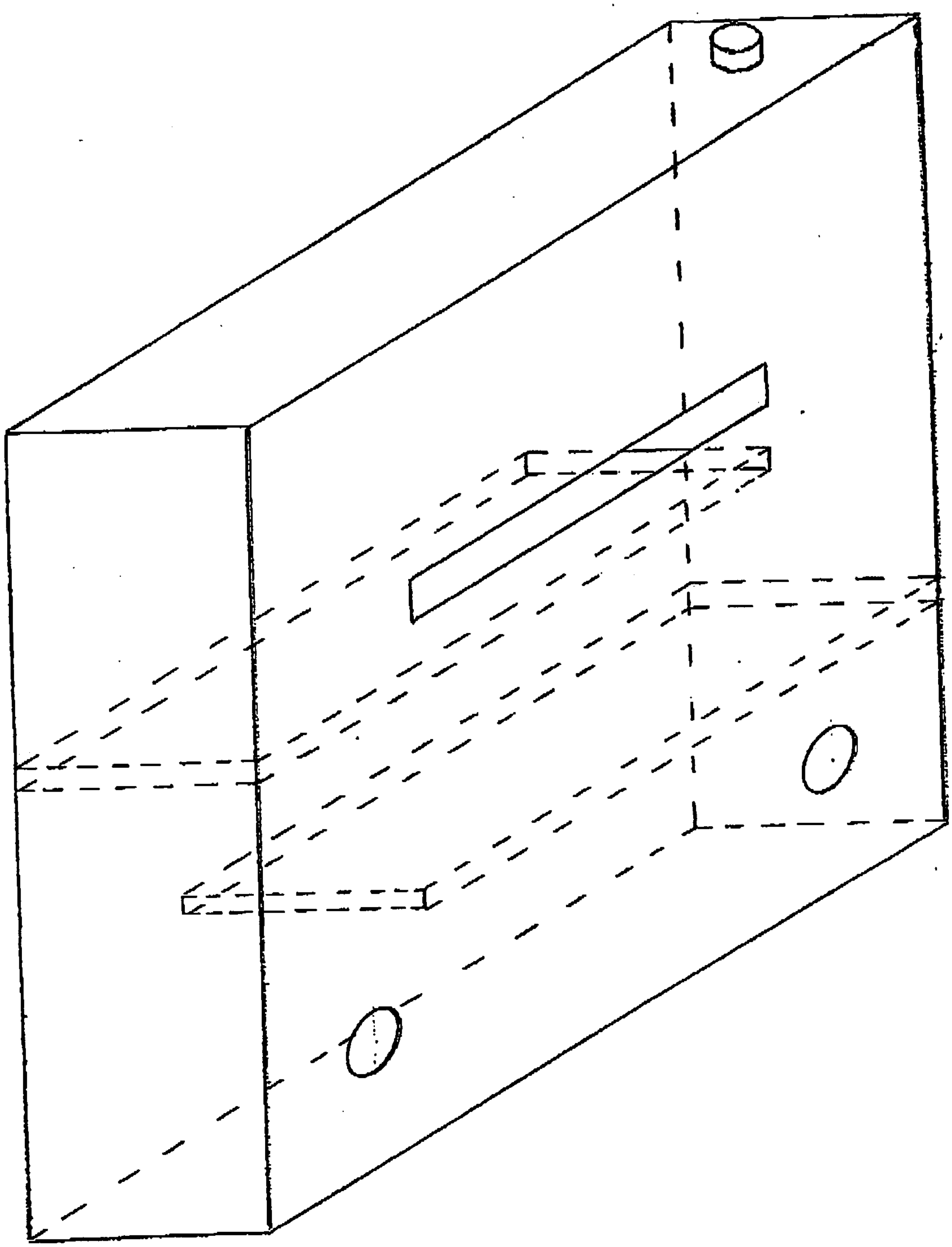


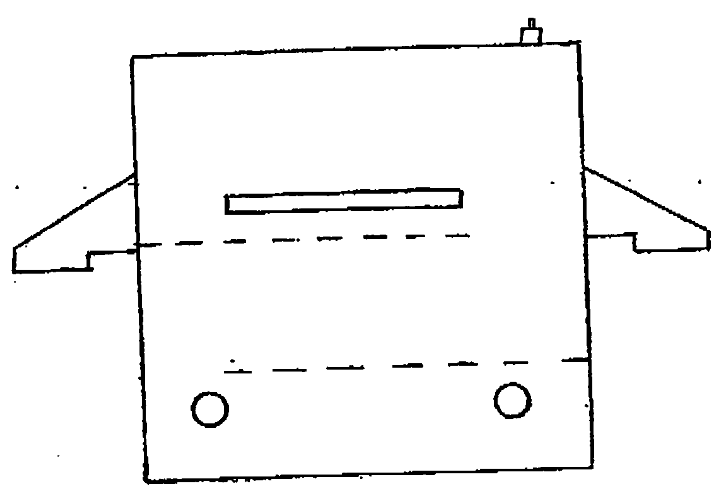


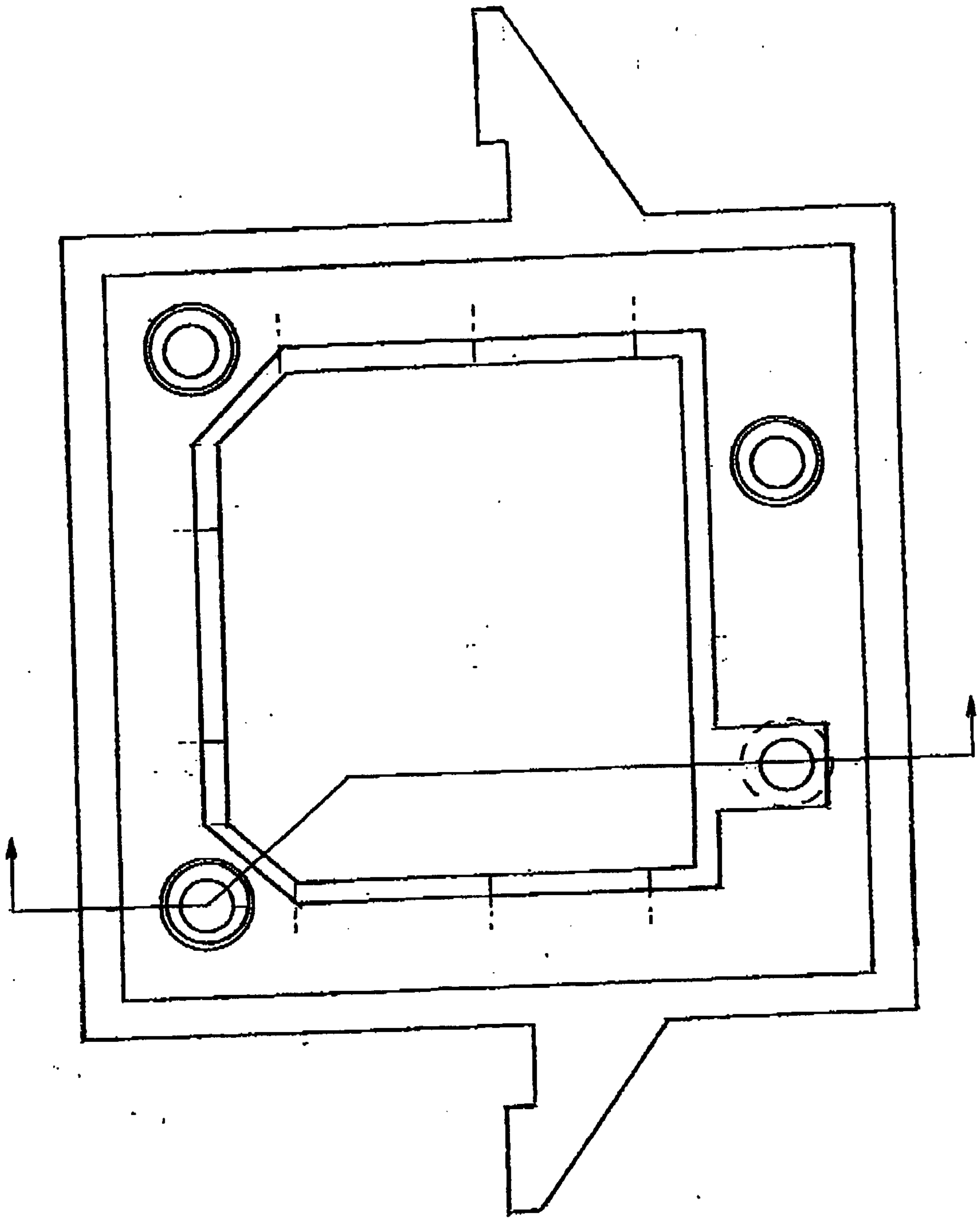












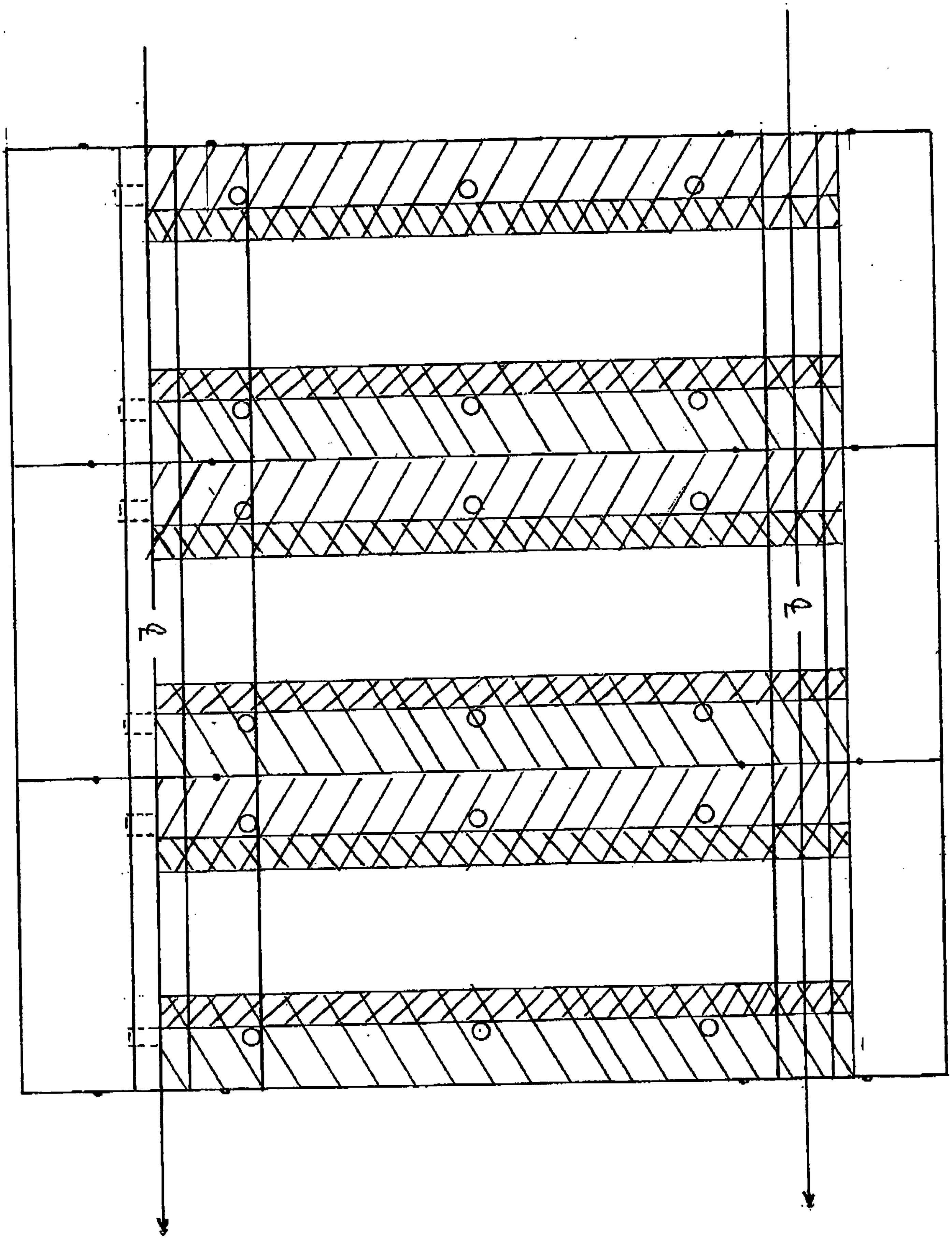


Exhibit 4

Lindquist, Terrie

From:	gus.ecolotron [gus.ecolotron@ev1.net]
Sent:	Friday, September 20, 2002 4:01 PM
To:	Rowald, Kent
Subject:	Patent II Text docs
Attachments:	Abstract.doc; Process & Apparatus-back ground Invention.doc; Summary of the Invention.doc; Claims.doc

Kent:

I have to split up docs into two or more E-Mails.

These are only the beginning.

Thank you:

Tom Gus Gavrel

ph: 281-339-5400

fax: 281-559-1121

ABSTRACT

An apparatus and system that uses an improved design for the high pressure electrocoagulative treatment of aqueous and/or viscous fluids and sludges. The apparatus is configured as a plate and frame design utilizing hydraulic or screw type mechanical closure on recessed, gasketed, non-electrically conductive spacer plates hereafter referred to as spacer plates that completely enclose and encase all fluids, electrical contacts, electrodes and fluid conduits within the confines of the spacer plates. The spacer plates include integral supports on the edges that hold and position said spacer plates and enclosed electrodes on top of the side rails of the supporting frame such that the spacer plates with enclosed electrodes may be opened or separated for electrode replacement or other maintenance and conversely closed, pressured and put into service. The apparatus also includes a baffled influent and a baffled effluent chamber and/or plate at both ends for the addition and flash mixing of chemical reagents and/or flocculants and also that provides a means of fluid communication with the fluid conduits formed by the interconnection of gasketed ports through the spacer plates and/or external conduits for fluids to enter and to exit the apparatus. Various physical, mechanical and/or organic separation means in fluid communication with the apparatus may or may not be utilized based on influent fluid characteristics and the desired goals and objectives of treatment.

Process and Apparatus for the Electrocoagulative treatment of Aqueous and Viscous Fluids

Background of the Invention

1. Field of the Invention

The present invention relates to a high pressure method for the treatment of aqueous and viscous fluids by means of flowing through a plurality of electrically charged electrodes therefore destroying or otherwise rendering harmless any undesirable living organisms and allowing any undesirable matter present therein to be subsequently removed such that once treated, the fluids may be classified as harmless or otherwise acceptable to humans, animals, insects, vegetation and the environment. The invention also relates to a plate and frame apparatus utilizing recessed, gasketed, non-conductive spacer plates with enclosed, exchangeable electrodes of various designs that are suspended on a supporting, square, elongate frame in such a way as to allow the spacer plates with electrodes to be easily separated or opened to exchange the electrodes or perform other maintenance and subsequently closed and pressured utilizing a hydraulic or screw type mechanical closure device that shall maintain sufficient closure/operating pressure to seal the plurality of said spacer plates with enclosed electrodes therefore containing pressured fluids within the confines of the plurality of chambers formed therein. The apparatus also incorporates (integral or non-integral with the supporting frame), influent and effluent mixing chambers and/or plates (with injection ports for chemical reagents) in fluid communication with conduits that may or may not be within the confines of said spacer plates allowing aqueous and viscous fluids to enter and exit the apparatus and multiple mechanical separation means in fluid communication with the apparatus to subsequently separate liquids from liquids, liquids from solids and/or for dewatering of the fluid.

2. Description of the Related Art

The present invention is directed to improving methods and apparatuses for the treatment and/or removal of undesirable matter and/or organisms present in solution, in suspension and/or in a stable state of emulsion in aqueous fluids such that said methods and apparatuses may process said fluids at increased flow rates and also may process said fluids having high viscosities (biological sludge, soil slurries, oil field drilling fluids, etc.) in an environmentally safe, economical, user friendly, easily manufactured and easily maintained manner. Many electrocoagulative treatment methods and apparatuses have been described in the literature dating as far back at 1901, Lacomme. The present invention incorporates unique engineering concepts that shall be apparent to those skilled in the art. Previous attempts to achieve engineering excellence are described in the forthcoming list of prior inventions and patents.

U.S. Patent No. 3,969,245, 7/1976 issued to Ramirez discloses an electorcoagulation method and apparatus utilizing a cylindrical cell with concentrically positioned electrodes for electrolitically generating large quantities of gas bubbles while simultaneously flowing wastewater through the cell to form an embryo floc which subsequently attaches to the gas bubbles to achieve clarification by floatation. Ramirez vented the electrocoagulation cell to atmosphere to avoid build up of pressure within the cell. Current environmental standards dictate that fugitive air emissions are unacceptable and present complex permitting issues. Venting to atmosphere also limits applications in which an apparatus or process may be implemented due to hazardous materials venting to atmosphere and risk of explosion.

U.S. Patent No. 5,928,493, 7/1999 issued to Morkovsky, et. al. relates to an electrocoagulation process and system for low pressure and low flow conditions incorporating an agitated defoam tank utilized for allowing entrained gasses to escape prior to entering a settling clarifier. The inclusion of a defoam tank increases the overall footprint, adds additional plumbing and mixing components and vents off gasses to atmosphere. For the afore mentioned reasons, this is unacceptable in many applications. The reactor cell housing with opposed grooved sides for retaining the electrode plates also presents problems. Because of the spacing of the plates, when fluid velocities reach a critical point the differential pressure through the reactor cell is too great and the reactor cell is susceptible to leaking creating house keeping issues, exposure of possible hazardous materials to workers and the environment and the release of off gases to the environment. This reactor cell design also depends on "links" which are a means of connecting electrical power to the electrodes. These "links" must be inserted between the closely spaced electrode plates and tightened by means of nuts, screws and/or bolts and becomes maintenance intensive when exchanging the electrode plates or performing other maintenance.

German Patent Document DE 3641365 A1, issued to Klose discusses an electroflotation device for purification and treatment of polluted water by flowing the water over bundles of iron and aluminum electrode plates. Electroflotation is described as a combination of chemical and physical actions whereby iron and aluminum are sacrificed from the anodes and (as with chemical precipitation), utilized as an oxide for flocculation. Electrolytic action between anodes and cathodes release oxygen gasses in the form of fine bubbles which enter into oxidation reduction reactions with substances in the water causing the precipitation of pollutants. Disinfection, metals removal and oil water emulsion splitting occurs and contaminants are removed by vacuuming floated material from the surface and removing bottom sediments via the sloped bottom of the vessel. This device utilizes a rectangular tank, again open to the atmosphere, non-pressured and is not applicable to viscous fluids or sludges.

As illustrated by the background of the invention, attempts to develop methods and devices for the removal of contaminants from fluids shall continue in the future as in the past. There has been no effort thus far that provides the benefits, advantages and unique engineering concepts as the present invention. The present invention is considerably unique in comparison to conventional engineering concepts and in doing so offers a means of causing undesirable matter to precipitate or co-precipitate from suspension and/or solution, the destabilization of suspended colloidal material, the destabilization of emulsions, and the disruption of undesirable living organisms utilizing distinctively unique recessed, gasketed, non-conductive spacer plates to enclose and hold in a place a variety of shaped electrodes while containing all fluids, electrical conduits and fluid conduits made up of interconnecting ports sealed by gaskets and capable of operating at high pressures such that viscous fluids may be pumped through the apparatus. Additionally, the uniqueness of the apparatus contains integral mixing chambers and a square or rectangular support frame utilizing hydraulic or screw mechanical closure allowing ease of manufacturing, cleaning, maintenance and operator safety.

Summary of the Invention

The present invention relates to an apparatus and system for treating aqueous and viscous fluids at high pressures comprising: a pump for transferring various fluids through an electrocoagulation device, a plate and frame electrocoagulation device, an effluent conduit in fluid communication with the electrocoagulation device incorporating a pressure regulation device and a physical, mechanical, and/or organic separation means connected to said effluent conduit before or after the pressure regulation device such that the pressure of the aqueous and/or viscous fluid may or may not be released through the physical, mechanical and/or organic separation means.

The plate and frame electrocoagulation device of the present invention consists of a plurality of recessed, gasketed, non-electrically conductive spacer plates hereafter referred to as spacer plates with integral supports on the edges that contain various shaped electrodes within the recessed boundaries of the spacer plates. The integral supports on the edges of the spacer plates rest on the side rails of a square or rectangular, elongate frame that is supported above grade by legs such that the spacer plate stack is arranged in a horizontal orientation. This in no way implies that the spacer plate stack cannot be oriented in a vertical orientation and in many applications it is favorable to orient the spacer plate stack in a vertical orientation. The electrodes may or may not be made of sacrificial material including iron or aluminum such that the electrode material will be sacrificed at the anodes in accordance with Faraday's Law when a voltage is applied to said electrodes. However, it may be beneficial to make the electrodes of a non-sacrificial material and/or coating said electrodes with a non-sacrificial material when oxidation, reduction, or organism/organic destruction by the electromotive force present within the device is the desired effect. Said electrodes plates may or may not be constructed such that they are slotted, perforated, pierced, crimped and/or be constructed of a porous, permeable or semi-permeable material. The afore mentioned spacer plates may or may not be constructed such that gasketed ports will align with each other when a plurality of spacer plates are closed against each other and pressed together such that the gasketed ports shall be interconnected forming conduits for fluid flow within the confines of an outer gasket located near the peripheral edge of the spacer plates. The peripheral gasket of the spacer plates contains all fluids, conduits and electrodes such that when closing/operating pressure is applied by a hydraulic or screw type mechanical closure means the system is totally isolated from the outside environment. The spacer plates also include highly electrically conductive metallic discs or rods that may be embedded in the spacer plates or inserted through gasketed ports through the spacer plates such that when a plurality of said spacer plates are pressed together under closing/operating pressure they shall form electrical conduits by interconnecting with each other to distribute an applied voltage throughout the device contacting selected enclosed electrodes. Said electrical conduits are within the confines of the afore mentioned peripheral gasket such that upon closure of the spacer plates said electrical conduits are totally isolated from the outside environment.

The electrocoagulation device includes baffled influent and effluent mixing chambers and/or plates (that may or may not be integral with the frame) at each end of the spacer plate stack for the addition and mixing of chemical reagents and/or flocculants and that also provides a means of fluid communication with the fluid conduits formed by the interconnecting gasketed ports through the spacer plates and/or external conduits for fluids entering and exiting the device. This arrangement allows for influent and effluent plumbing to be located on one end of the device and also allows for the hydraulic and/or screw type mechanical closure means to be located on the opposite end of the device such that closing/operating pressure may be applied to the spacer plate stack. Said closing/operating pressure shall be greater than the influent pumping pressure such that closure is maintained containing all fluids within the confines of the peripheral gasket of the spacer plates such that the fluids are totally isolated from the outside environment. The influent mixing chamber/plate may or may not extend through the head stock of the frame such that it is in fluid communication with a riser conduit connected by a tee (T) with said riser conduit being of higher elevation than the spacer plate stack and terminating by means of a pressure regulating device that may or may not be actuated for the purpose of (1) collecting any air or other gasses that may be present in an influent aqueous fluid so that said gasses may be released such that said gasses may not enter the electrocoagulation device and thus reduce the electrical conductivity of said fluid and (2) provide a passive relief valve that may be set for a selected, maximum operating pressure such that the safe operating pressure of the electrocoagulation device may not be exceeded therefore preventing the release of hazardous and/or non-hazardous fluids and/or material to the outside environment. Said pressure regulating device shall be connected to a conduit that shall return any released fluids to the storage, equalization and/or collection tank or vessel containing the fluid before transfer to the electrocoagulation device. The two effluent conduits that may or may not extend through the head stock of the frame and may or may not be in fluid communication by means of a manifold shall connect to the effluent conduit that is in fluid communication with a physical, mechanical, and/or organic separation means and shall be connected to said separation means through a pressure regulating device such that pressure is maintained on the electrocoagulation device such that gasses may not evolve as a result of electrolysis until pressure on the fluid is released upon entry to the separation device. This is done to (1) keep evolved gasses (O_2 or H_2) in solution so that they are available for oxidation reduction reactions (2) to prevent gas bubbles from reducing the electrical conductivity of the fluid as it flows through the electrocoagulation device and (3) allowing the evolved gasses to be utilized for flotation clarification upon entry to the dissolved air/gas flotation chamber where liquid-liquid and/or liquid-solids separation occurs. When dissolved air/gas flotation is used as the separation means, a riser conduit shall be connected to the effluent conduit before said pressure regulation device by means of a Tee (T) as afore mentioned at the influent riser before entry to the electrocoagulation device. Said effluent riser is utilized as (1) a redundant passive relief valve that can be set at a selected operating pressure such that the

safe operating pressure of the electrocoagulation device is not exceeded preventing the release of fluids and other materials to the outside environment and (2) to accumulate any gasses that may have evolved such that they may be released as not to allow large bubbles to enter into the flotation chamber where they may disrupt proper flotation mechanics.

The afore mentioned physical, mechanical separation device, (dissolved air/gas flotation chamber) may or may not be substituted with other physical, mechanical and/or organic separation means depending on the nature of the fluid, the undesirable matter and/or living organisms present therein, and the desired goals and objectives of treatment. Said physical, mechanical and/or organic separation means are preferably a two phase or three phase decanting centrifuge as used for dewatering of biological sludges and separating oil, water and solids, a membrane concentration system and/or a membrane bioreactor as used for removal of dissolved organic species, hydro cyclones as used for separating selected liquids-solids and liquids-liquids from soil slurries and oil field drilling fluids, a rotary or belt press as used for dewatering of biological sludges and/or a plate and frame filter press as utilized for dewatering of hazardous sludges.

Important features have been broadly presented as to allow a better understanding of the detailed description that follows such that those skilled in the art may appreciate the unique contributions and engineering concepts of the present invention. It shall be understood by those skilled in the art that specific methods and structures described herein may be incorporated into differing designs that may be used to accomplish the same and/or similar objectives. It shall be understood that additional objects, if not set forth specifically herein, will be readily apparent to those skilled in the art from the following detailed description and from the drawings.

We claim:

(1) An apparatus and system that uses an improved design for the high pressure electrocoagulative treatment and subsequent removal of undesirable matter and organisms in suspension, in solution and/or in a stable state of emulsion in aqueous and viscous fluids and sludge comprising:

- A plate and frame design utilizing hydraulic or screw type mechanical closure and pressure on a plurality of recessed, gasketed, non-conductive spacer plates that completely or partially enclose square, rectangular, offset pentagonal and hexagonal or rod shaped electrodes in such a way as to form chambers through which an aqueous and/or viscous fluid may flow and may or may not come into contact with the electrode surfaces and also be exposed to the electromotive force present therein;
- Applying a voltage to said electrodes in such a way as to produce an alternating sequence of positive and negative electric potentials and thus introducing a continuous flow of electrical current through the aqueous and viscous fluid flowing through said chambers;
- Reacting with undesirable matter and/or organisms present in suspension, in solution and/or in a stable state of emulsion in the aqueous and/or viscous fluid with material sacrificed from the electrode surfaces and/or the electromotive force induced by said applied voltage within the apparatus in such a way as to cause the destabilization of colloidal particulates and/or emulsions, the direct chemical replacement and precipitation of substances, the co-precipitation of substances and/or disrupting the osmotic interchange of fluids through permeable, semi-permeable and/or other membrane boundaries of undesirable living organisms such as bacteria, viruses and/or cysts therefore causing the implosion or explosion of the organisms rendering them harmless to humans, animals, insects, vegetation and/or the environment; Question: Polarity reversal?
- A physical, mechanical and/or organic separation means in fluid communication with said apparatus via a conduit with a pressure release valve located at the point of entry to the mechanical separation device such that pressure is maintained within the apparatus and the conduit such that any evolved gasses shall be maintained in solution within the apparatus and the conduit such that said non-evolved gases shall be available for oxidation/reduction reactions with undesirable matter and/or organisms in solution, in suspension and/or in a stable state of emulsion in the aqueous and/or viscous fluid;
- Said physical, mechanical and /or organic separation means is preferably (1) a dissolved air/gas flotation chamber as utilized for aqueous fluids such as water and wastewater, (2) a two phase and/or three phase decanting centrifuge as utilized for the disinfection (destruction of pathogens) and subsequent dewatering of biological sludge, liquefied manure and/or the separation of oil, water and solids, (3) a membrane concentration system and/or membrane bioreactor as utilized for concentrating and/or elimination of organic substances, (4) hydro

cyclones as utilized for soil slurries and oilfield drilling fluids, (5) a rotary and/or belt press as utilized for dewatering biological sludge and/or (6) a plate and frame filter press as utilized for dewatering of hazardous sludge.

(2) An apparatus and system as recited in claim (1), wherein the hydraulic or otherwise screw type mechanical closure pressure on the recessed, gasketed,, non-conductive spacer plates with electrodes is greater than the influent pumping pressure of the aqueous and/or viscous fluid being pumped through the apparatus such that the apparatus contains all fluids and substances within the confines of the chambers formed by the recessed, gasketed, non-conductive spacer plates;

➢ Question: Do we need to claim slots at alternating ends of electrode plates such that a serpentine or sinuous path is followed by the fluid?

➢ Question: intermediate electrode plates (w/o change) as voltage separators?

(3) An apparatus and system as recited in claim (1) wherein the recessed, gasketed, non-conductive spacer plates posses integral supports on the edges such that the spacer plates with enclosed electrodes shall rest on the side rails of a square or rectangular elongated frame and are free to be opened and closed for electrode replacement and/or other maintenance of the apparatus;

(4) An apparatus and system as recited in claim (1) that includes baffled influent and baffled effluent chambers and/or plates at one or both ends that may or may not be integral with the square or rectangular elongated frame for; <1> the addition of chemical reagents and/or flocculants and <2> also provides a means of fluid communication to an influent and/or effluent conduit that may or may not be within the confines of the gasketed spacer plates for aqueous and/or viscous fluids entering or exiting the apparatus.

(5) An apparatus and/or system as recited in claim (4) wherein the effluent fluid conduit is formed by the interconnection of gasketed ports in the recessed, gasketed, non-conductive spacer plates.

(6) An apparatus and/or system as recited in claim (5) (or claim 1-?) wherein the means of dispersing the electrical current to the electrodes is accomplished by a buss bar that is formed by metallic discs or rods embedded within the confines of the recessed, gasketed non-conductive spacer plates in such a way that they contact each other and the enclosed electrodes forming a continuous electrical conduit when closure pressure is applied to the plurality of spacer plates;

(7) An apparatus and/or system as recited in claim (6) (or claim 1) wherein square electrodes may be larger than the recessed, gasketed, non-conductive spacer plates such that the exposed, square corners of the electrodes may be connected to an external, flat buss bar by means of integral, flat clamps that snap onto and off of the exposed edges of said electrodes thus providing a less expensive, easily maintained configuration that may be used in non-explosive environments;

(8) An apparatus and system as recited in claim (7) wherein the recessed, gasketed, non-conductive spacer plates are in the shape of an offset pentagram, hexagram, or octogram such that the square corners of the larger square electrodes may be exposed in such a way as to allow a flat buss bar with integral clamps to snap onto and off of the exposed corners or edges of the electrodes;

Exhibit 5

Lindquist, Terrie

From: gus.ecolotron [gus.ecolotron@ev1.net]
Sent: Tuesday, October 01, 2002 11:23 AM
To: Rowald, Kent
Subject: Patent
Attachments: Description of the preferred Embodiment.doc

Kent:

Please find attached document concerning details of thepreferred embodiment.

I will call you shortly.

Thank you:

Tom Gus Gavrel

ph: 281-339-5400

fax: 281-559-1121

Description of the preferred Embodiment

Referring to FIG. 1, fluids 110 collected in tank 100 are pumped through an interconnecting influent pipe 116 by means of a pump 115 to the high pressure, plate frame electrocoagulation apparatus 140. An actuated valve 125 is located in the interconnecting influent pipe 116 to contain fluids 110 in the collection tank 100 when the system is not in operation. Pump 115 is typically a centrifugal pump for low viscosity fluids and/or a progressive cavity pump for high viscosity fluids, slurries and/or sludge and is capable of variable flow rates and high pressures (10 to 225 psi). A riser pipe 138 is connected to the interconnecting influent pipe 116 at a higher elevation than the electrocoagulation apparatus 140 to collect any undissolved gas that may be present in the fluid 110 and venting said gas through pressure regulator valve 139 preventing any undissolved gas from entering the electrocoagulation apparatus 140. Gases are resistive to electrical current and reduce the electrical conductivity of influent fluids 110 inhibiting treatment. Pressure regulator valve 139 also provides passive pressure release in the event that unsafe pressures are encountered. Influent pressure of the fluid 110 is monitored by the pressure sensor 135 which transmits a variable signal proportional to said pressure to the controller 130. The controller may be a computerized PLC and/or other configured system utilizing analog and discreet inputs and outputs for data logging and activating automated devices. Two injection ports 126 are connected to the interconnecting influent pipe 116 for the addition of chemical reagents for

desired oxidation reduction reactions and pressurized air for evacuating fluids from the electrocoagulation apparatus 140 when maintenance is required.

The electrocoagulation apparatus 140 is connected to a power supply 145 that provides an applied voltage to said apparatus. The applied voltage may be an alternating, direct and/or a pulsed current. For the purposes of this discussion, the applied voltage shall be described as a direct current and voltage applied to the terminal connections 128 of the electorcoagulation apparatus 140. As the pressured fluid 110 flows through the electrocoagulation apparatus 140 various reactions occur as described in our co-pending U.S. Patent application Ser. No. 60/244,615 and in the forthcoming details. As the pressurized fluids 110 exit the electrocoagulation apparatus 140, a preferred but not essential method step is the injection of a flocculent aid via injection port 127 to assist with subsequent separation methods. Pressurized fluids 110 exit the electrocoagulation apparatus 140 by means of the interconnecting effluent pipe 117 with attached temperature sensor 137 which monitors the temperature of the effluent fluids 110 and transmits a variable signal proportional to the temperature to the controller 130. The interconnecting pipe 117 is connected to an actuated pressure regulator valve 154 by raiser pipe 153 such that the elevation of the riser pipe 153 is higher than the electrocoagulation apparatus 140 and the subsequent separation means 150 and collects any undissolved gases that may be present in the pressurized fluid 110 and periodically purges said gases from the system to ensure that no undissolved gases enter the subsequent separation means 150. The pressure regulator valve 154 also provides passive pressure relief in the event that unsafe pressures are encountered.

Pressure of the effluent pressurized fluid 110 is monitored by the pressure sensor 136 which transmits a variable signal proportional to said pressure to the controller 130. The pressurized fluid 110 may enter a variety of physical, mechanical and/or organic separation means 150 through pressure regulator valve 152 and pressure on the fluid 110 is dissipated as separation occurs by flotation, sedimentation, filtration and/or centrifugal force depending on the mechanism of the physical, mechanical and/or organic separation means 150. Treated fluid 110 exits the separation means 150 by means of a fluid conduit or pipe 118 connected to said separation means 150 by actuated valve 200. Separated materials removed from the fluids 110 are collected in a holding vessel 159 for further disposition by a transfer pump 160.

FIG. 2 and FIG. 3 show four elevated views of the high pressure plate and frame electrocoagulation apparatus 140 of the present invention. Together with FIG. 4, a horizontal cross section through the Z-axis viewing from the front of the head stock 122, details of the structure of the supporting frame become apparent to those skilled in the art. The supporting frame of the preferred apparatus comprises a rectangular, solid steel head stock 122 and tail stock 124 welded to two, heavy duty rectangular steel tubing side rails 142 perpendicular to said head stock 122 and tail stock 124 forming an elongate frame above grade for supporting, positioning and holding closure pressure on a plurality of electrocoagulation spacer plates 300 hereafter refereed to as ES P's (ESP's are defined in the objects of the present invention and shall be discussed in detail in the forthcoming text). The ESP's 300 ride on the top of the side rails 142 of the supporting frame and may be separated or opened for accessing internal components and subsequently closed and pressured by

the hydraulic closure mechanism 144 that is integrally attached to the tail stock 124 and the push plate 146. The push plate 146 also rides on top of the side rails 142 and is held in a perpendicular position by two rollers 148. A spool piece 147 may or may not be included to allow for future expansion, different configurations of the apparatus and/or incorporation of multiple power supplies by segregating groups of ESP's 300.

The head stock 122 of the preferred apparatus is constructed of solid steel providing a supporting leg for the apparatus and a means for attachment of the two side rails 142. Electrical contact terminals 128 are inserted through two ports 311 near the top of the head stock 122 providing a means for the applied voltage supplied by the power supply 145 to contact internal components. The external electrical contact utilizes standard explosion proof conduit-junctions that are familiar to those skilled in the art. Two through wall ports 121 are located near the bottom corners of the head stock 122 and are in fluid communication with internal, effluent conduits 149 providing a means for fluids 110 to exit the apparatus. Although only two effluent ports 121 are shown, more may be utilized determined by the application. The two effluent ports 121 are connected to an effluent manifold 123 which is in fluid communication with the interconnecting effluent pipe 117. Effluent temperature sensor 137 and effluent pressure sensor 136 are located in the interconnecting effluent pipe 117 to monitor temperature and pressure of the pressurized fluid 110 as it exits the apparatus and transmit variable signals proportional to the temperature and pressure to the controller 130. The interconnecting influent pipe 116 is in fluid communication with the influent feed

pump 115 (FIG. 1) and incorporates actuated valve 125 used for segregating the system from the collection tank 100 and allowing the apparatus to be depressurized by opening pressure regulator valve 139 and/or pressure regulator valves 154 and 152 (FIG. 1). Integral with the influent interconnecting pipe 116 are two injection ports 126 for the addition of chemical reagents that may or may not be utilized for oxidation reduction and/or other desired reactions, and air for blowing down the apparatus to evacuated fluids 110 from the apparatus prior to or during depressurization and subsequent opening for inspection and maintenances. A riser pipe 138 is connected to the influent interconnecting pipe 116 behind the injection ports 126 and before the influent conduit 325 through the head stock 122 providing a means of collecting any gases not in solution and purging said gases to the collection tank 100 to avoid inclusion of said gases in the influent pressurized fluid 110 avoiding a reduction of electrical conductivity in the influent fluid 110. Integral with the riser pipe 138 are pressure regulator valve 139 and influent pressure sensor 135 which monitors influent fluid 110 pressure and transmits a variable signal proportional to said pressure to the controller 130. Pressure regulator valve 139 also provides passive pressure relief by receiving a signal from the controller 130 to open when a pre-set, limiting pressure is detected thereby avoiding an unsafe condition.

The tail stock 124, like the head stock 122, also provides a support leg for the apparatus and a means of welded attachment for the two side rails 142. The tail stock 124 also provides a means of supporting the integrally attached hydraulic closure mechanism 144 for opening, closing and maintaining pressure on the closed

stack of ESP's 300. The hydraulic closure mechanism 144 is an air operated closure mechanism lockable in the closed position that is capable of maintaining sufficient closure pressure to allow influent pumping and operating pressure of the fluid 110 at 110 psi. Closure pressure is directly correlatable to the cross sectional surface area of the ESP 300 stack and will vary with the size of the preferred apparatus. All hydraulic components and a local control panel 220 are integral with and enclosed within the tail stock 124 and include pneumatic and hydraulic pressure relief bypass means (not shown) to avoid damage to the apparatus in a malfunction condition. All integral, internal hydraulic components, air headers, pumps, air regulators etc. are accessible to the operator through an access door 143 in the tail stock 124.

FIG. 5, 6, 10, and 16 show front and side views of ESP's of the preferred apparatus and together with FIG. 14, an isometric and cross-sectional view of a plurality of ESP's shown in a closed position without the supporting frame, and FIG. 7 and 17, views of electrodes 141 of the preferred apparatus, the mechanism of fluid 110 transport through the apparatus and distribution of the applied voltage throughout the apparatus will become apparent.

ELECTROCOAGULATION SPACER PLATES (300), hereafter referred to as ESP's, are defined as flat, recessed, gasketed, ported devices constructed of non-electrically conductive materials comprising an internal cavity 305 for supporting and containing various shaped electrodes 141 within confined boundaries such that when a plurality of like devices is stacked together, an internal, elongate cavity 221 with multiple, parallel tubular conduits is isolated within. ESP's are typically square and/or offset hexagonally shaped. FIG. 14 is an isometric view of a plurality of

ESP's 300 stacked together without a supporting frame or electrodes 141 showing the internal elongate cavity 221 and surrounding parallel conduits 222 within. When flat, ported electrodes 141 are enclosed within the recessed boundaries 224 of the closed ESP's 300, a plurality of perpendicular chambers 223 is isolated within the internal, elongate cavity 221 such that fluids 110 may flow through a path dictated by the shape and location of any openings in the flat, enclosed electrodes 141. In this illustration the preferred shape and location of said openings are rectangular ports 226 located at alternating ends therefore dictating a meandering or sinuous path. Said ports may be circular, rectangular, etc. and may be located at alternating tops and bottoms of electrodes 141, at alternating right and left sides of electrodes 141 and/or any combination of said locations as to dictate a meandering or sinuous flow pattern and/or a spiral or conical flow pattern. When an applied voltage is connected to the terminals 128 of the apparatus and distributed throughout the apparatus such that alternating positive (+) and negative (-) electric potentials are realized by the enclosed electrodes 141 while fluids 110 are flowing through the dictated sinuous path, an electric current flows from electrode 141 to electrode 141 and therefore through the pressurized fluid 110 circulating through the apparatus.

The means of distributing the applied voltage throughout the apparatus is accomplished by interconnecting, metallic inserts 310 that are embedded and/or inserted in the upper, gasketed ports 301 of the ESP's such that when a plurality of ESP's 300 are closed and held together said metallic inserts 310 contact each other, the power contact 303 of selected electrodes 141, and the electrical terminal contacts

128 located at the head stock 122, thereby defining a continuous electrical conduit (FIG.4/312) and a complete circuit for distribution of electrical power. All ports 301 & 304 within the body of the ESP's 300 are individually contained by port gaskets 302 that are inserted into grooved recesses such as to hold said port gaskets 302 in place and seal said ports 301 and 304 containing and isolating same from fluid intrusion as with upper electrical ports 301 and/or fluid extrusion as with the case of the lower fluid ports 304 used for effluent fluid conduits 149 (FIG. 4) formed when a plurality of ESP's are closed and held together. A peripheral gasket 307 is positioned within a like recessed groove located around the outer perimeter of the ESP's 300 thereby containing all internal cavities 305, all gasketed ports used for electrical purposes 301, metallic inserts used for electrical conduits 310, all gasketed ports used as fluid conduits 304, and pressured fluids 110 within the confines of said peripheral gasket 307 and ESP's 300 isolating same from the outside environment. ESP's may or may not be single recessed FIG. 5 and FIG. 6 meaning that the internal recessed boundary support 224 with rectangular recession 306 for location of selected electrode power contact 303, is located on only one surface for enclosing and positioning of one electrode 141 and/or double recessed FIG. 10 and meaning that the ESP's 300 contain internal recessed boundary supports 224 on both surfaces for enclosing and positioning of two electrodes 141. A double recessed ESP 300 may be utilized with one powered electrode 141, using the second recessed boundary support 224 to position a non-powered baffle surface creating a longer fluid path within the apparatus for (1) increasing the dwell time (reaction time) that the fluid 110 being treated is exposed to the electromotive force present within the

apparatus and (2) increasing the distance between powered electrodes 141 requiring a higher applied voltage resulting in increased electrolysis and increased release of oxygen (O_2) and hydroxyl (OH^-) ions available in solution for oxidation reduction reactions. When a non-powered baffle plate is incorporated in the second recessed boundary support 224 of a double recessed ESP 300, said baffle plate is held in position by pins 315, inserted parallel to the outer surface of said baffle plate and perpendicular to the recessed boundary support 224 edge (FIG. 10). The extended, rectangular recession 306 that is integral with the internal recessed boundary support 224 for contacting selected electrodes 141 may be located in the right position as shown in FIG. 5 or in the left position as show in FIG. 6 to receive the electrode power contact 303 of selected electrodes 141. ESP's 300 rest vertically within the two side rails 142 of the supporting frame by means of a slotted, integral support 308 using the rectangular shaped slot 309 for positioning and alignment on the rectangular tubing of said side rails 142.

FIG. 8 is an isometric and front view of an influent mixing chamber plate 320 (the isometric view omits integral supports) that may or may not be attached to the head stock 122. It is comprised of many like features in that there are two upper gasketed ports 301 used to contain metallic inserts 310 and two, lower gasketed ports 304 used for fluid transport, but this device does not contain and position any electrodes 141. The influent mixing chamber plate 320 has a centrally located influent conduit 325 that protrudes through the influent port 151 in the head stock 122 and is in fluid communication with the interconnecting influent pipe 116 thereby allowing pressurized fluids 110 to enter the apparatus. It is a hollow

structure with internal baffles 321 oriented such that the fluid 110 direction is reversed when traversing through the chamber, agitating said fluid 110 to mix any chemical reagents that may be injected via the injection ports 126 in the interconnecting influent pipe 116. There is a rectangular port 322 located at the bottom of the back wall 323 to allow the pressurized fluid 110 to flow through. All tubular ports 301 and 304 extend from the front wall 324 to the back wall 323 isolating same from the internal chamber between. The influent mixing chamber plate 320 is constructed of non-electrically conductive materials and isolates electrical contact with the head stock 122 and side rails 142 like ESP's 300.

FIG. 9 is an isometric and front view of the effluent mixing chamber plate 330 (the isometric view is shown without integral supports). It is so named because it receives fluid flow through the influent, rectangular port 335 located on the upper portion of the front surface 331 and redirects fluid flow to the head stock 122 of the apparatus via the two gasketed fluid ports 304 located at the bottom inside surface 331. The lower, gasketed, fluid ports 304 align with like gasketed ports 304 in adjacent chambers thereby comprising a continuous fluid conduit 149 (FIG. 4) within confined boundaries isolated from the outside environment. An injection port 127 is located at one side where fluid flow is reversed by one of two internal baffles 332 for injection and flash mixing of a flocculent aid and/or chemical reagents. The back surface 333 of the effluent mixing chamber plate 330 is contacted by the push plate 146 which is connected to the hydraulic closure mechanism 144 providing closure pressure for the apparatus. Like the influent mixing chamber plate 320, the effluent mixing chamber plate 330 contains no

electrode 141. Its purpose is to redirect fluid flow to the head stock 122, provide an injection means 127 for flocculent and/or chemical reagents and mix same via internal baffles 332, provide a means of contact to the push plate 146 and provide a means of electrical insulation to the supporting frame.

Exhibit 6

Lindquist, Terrie

From:	gus.ecolotron [gus.ecolotron@ev1.net]
Sent:	Friday, October 04, 2002 3:38 PM
To:	Rhebergen, Constance
Cc:	Rowald, Kent
Subject:	Patent
Attachments:	Process & Apparatus-back ground Invention.doc; Summary of the Invention.doc; Abstract.doc; Brief Description of Drawings.doc; Claims.doc; Description of the preferred Embodiment.doc; Objects.doc

Constance:
Please find attached files concerning patent application.
Please do not hesitate to call with any questions orcomments.
Thank you:

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High Pressure Process and Apparatus for the Electrocoagulative treatment of Aqueous and Viscous Fluids

Background of the Invention

1. Field of the Invention

The present invention relates to a high pressure method for the treatment of aqueous and viscous fluids by means of flowing through a plurality of electrically charged electrodes therefore destroying or otherwise rendering harmless any undesirable living organisms and allowing any undesirable matter present therein to be subsequently removed such that once treated, the fluids may be classified as harmless or otherwise acceptable to humans, animals, insects, vegetation and the environment. The invention also relates to a plate and frame apparatus utilizing recessed, gasketed, non-conductive spacer plates with enclosed, exchangeable electrodes of various designs that are suspended on a supporting, square, elongate frame in such a way as to allow the spacer plates with electrodes to be easily separated or opened to exchange the electrodes or perform other maintenance and subsequently closed and pressured utilizing a hydraulic or screw type mechanical closure device that shall maintain sufficient closure/operating pressure to seal the plurality of said spacer plates with enclosed electrodes therefore containing pressured fluids within the confines of the plurality of chambers formed therein. The apparatus incorporates influent and effluent mixing chambers (containing injection ports for chemical reagents) in fluid communication with conduits that may or may not be within the confines of said spacer plates and interconnecting influent and effluent piping allowing fluids to enter and exit the apparatus. Multiple mechanical separation means in fluid communication with the apparatus are used to subsequently separate liquids from liquids, liquids from solids and/or for dewatering of the fluid.

2. Description of the Related Art

The present invention is directed to improving methods and apparatuses for the treatment and/or removal of undesirable matter and/or organisms present in solution, in suspension and/or in a stable state of emulsion in aqueous fluids such that said methods and apparatuses may process said fluids at increased flow rates and also may process said fluids having high viscosities (biological sludge, soil slurries, oil field drilling fluids, etc.) in an environmentally safe, economical, user friendly, easily manufactured and easily maintained manner. Many electrocoagulative treatment methods and apparatuses have been described in the literature dating as far back at 1901, Lacomme. The present invention incorporates unique engineering concepts that shall be apparent to those skilled in the art. Previous attempts to achieve engineering excellence are described in the forthcoming list of prior inventions and patents.

U.S. Patent No. 3,969,245, 7/1976 issued to Ramirez discloses an electorcoagulation method and apparatus utilizing a cylindrical cell with concentrically positioned electrodes for electrolitically generating large quantities of gas bubbles while simultaneously flowing wastewater through the cell to form an embryo floc which subsequently attaches to the gas bubbles to achieve clarification by floatation. Ramirez vented the electrocoagulation cell to atmosphere to avoid build up of pressure within the cell. Current environmental standards dictate that fugitive air emissions are unacceptable and present complex permitting issues. Venting to atmosphere also limits applications in which an apparatus or process may be implemented due to hazardous materials venting to atmosphere and risk of explosion.

U.S. Patent No. 5,928,493, 7/1999 issued to Morkovsky, et. al. relates to an electrocoagulation process and system for low pressure and low flow conditions incorporating an agitated defoam tank utilized for allowing entrained gasses to escape prior to entering a settling clarifier. The inclusion of a defoam tank increases the overall footprint, adds additional plumbing and mixing components and vents off gasses to atmosphere. For the afore mentioned reasons, this is unacceptable in many applications. The reactor cell housing with opposed grooved sides for retaining the electrode plates also presents problems. Because of the spacing of the plates, when fluid velocities reach a critical point the differential pressure through the reactor cell is too great and the reactor cell is susceptible to leaking creating house keeping issues, exposure of possible hazardous materials to workers and the environment and the release of off gases to the environment. This reactor cell design also depends on "links" which are a means of connecting electrical power to the electrodes. These "links" must be inserted between the closely spaced electrode plates and tightened by means of nuts, screws and/or bolts and becomes maintenance intensive when exchanging the electrode plates or performing other maintenance.

German Patent Document DE 3641365 A1, issued to Klose discusses an electroflotation device for purification and treatment of polluted water by flowing the water over bundles of iron and aluminum electrode plates. Electroflotation is described as a combination of chemical and physical actions whereby iron and aluminum are sacrificed from the anodes and (as with chemical precipitation), utilized as an oxide for flocculation. Electrolytic action between anodes and cathodes release oxygen gasses in the form of fine bubbles which enter into oxidation reduction reactions with substances in the water causing the precipitation of pollutants. Disinfection, metals removal and oil water emulsion splitting occurs and contaminants are removed by vacuuming floated material from the surface and removing bottom sediments via the sloped bottom of the vessel. This device utilizes a rectangular tank, again open to the atmosphere, non-pressured and is not applicable to viscous fluids or sludges.

As illustrated by the background of the invention, attempts to develop methods and devices for the removal of contaminants from fluids shall continue

in the future as in the past. There has been no effort thus far that provides the benefits, advantages and unique engineering concepts as the present invention. The present invention is considerably unique in comparison to conventional engineering concepts and in doing so offers a means of causing undesirable matter to precipitate or co-precipitate from suspension and/or solution, the destabilization of suspended colloidal material, the destabilization of emulsions, and the disruption of undesirable living organisms utilizing distinctively unique recessed, gasketed, non-conductive spacer plates to enclose and hold in a place a variety of shaped electrodes while containing all fluids, electrical conduits and fluid conduits made up of interconnecting ports sealed by gaskets and capable of operating at high pressures such that viscous fluids may be pumped through the apparatus. Additionally, the uniqueness of the apparatus contains integral mixing chambers and supporting frame utilizing a hydraulic mechanical closure means allowing ease of maintenance, cleaning, and operator safety.

Summary of the Invention

The present invention relates to an apparatus and method for treating aqueous and viscous fluids at high pressures comprising: a pump for transferring various fluids through an electrocoagulation device, a high pressure plate and frame electrocoagulation device, an effluent conduit in fluid communication with the electrocoagulation device incorporating a pressure regulation device and a physical, mechanical, and/or organic separation means connected to said effluent conduit before or after the pressure regulation device such that the pressure of the aqueous and/or viscous fluid may or may not be released through the physical, mechanical and/or organic separation means.

The high pressure plate and frame electrocoagulation device of the present invention consists of a plurality of recessed, gasketed, non-electrically conductive spacer plates hereafter referred to as spacer plates with integral supports on the edges that contain various shaped electrodes within the recessed boundaries of the spacer plates. The integral supports on the edges of the spacer plates rest on the side rails of a square or rectangular, elongate frame that is supported above grade by legs such that the spacer plate stack is arranged in a horizontal orientation. This in no way implies that the spacer plate stack cannot be oriented in a vertical direction and in many applications it is favorable to orient the spacer plate stack in a vertical direction. The electrodes may or may not be made of sacrificial material including iron or aluminum such that the electrode material will be sacrificed at the anodes in accordance with Faraday's Law when a voltage is applied to said electrodes. However, it may be beneficial to make the electrodes of a non-sacrificial material and/or coating said electrodes with a non-sacrificial material when the desired effect is oxidation and reduction or organism/organic destruction by the electromotive force present within the device. Said electrodes may or may not be constructed such that they are slotted, perforated, pierced, crimped and/or be constructed of a porous, permeable or semi-permeable material. The afore mentioned spacer plates may or may not be constructed such that gasketed ports will align with each other when a plurality of spacer plates are closed against each other and pressed together such that the gasketed ports shall be interconnected forming conduits for fluid flow within the confines of an outer gasket located near the peripheral edge of the spacer plates. The peripheral gasket of the spacer plates contains all fluids, conduits and electrodes such that when closing/operating pressure is applied by a hydraulic mechanical closure means the system is totally isolated from the outside environment. The spacer plates also include highly electrically conductive metallic discs, rods, and/or inserts that may be embedded in the spacer plates or inserted through gasketed ports through the spacer plates such that when a plurality of said spacer plates are pressed together under closing/operating pressure they shall form electrical conduits by interconnecting with each other to distribute an applied voltage throughout the device and contact selected enclosed electrodes. Said electrical conduits are within the confines of the afore mentioned peripheral gasket such that upon closure of the spacer plates said electrical conduits are totally isolated from the outside environment.

The electrocoagulation device includes baffled influent and effluent mixing chambers at each end of the spacer plate stack for the addition and mixing of chemical reagents and/or flocculants and also provide a means of fluid communication between fluid conduits formed within the apparatus by the interconnecting ports and cavities of the spacer plates and the interconnecting piping allowing fluids to enter and exit the device. This arrangement allows for influent and effluent plumbing to be located on one end of the device and also allows for the hydraulic mechanical closure means to be located on the opposite end of the device so that closing/operating pressure may be applied to the spacer plate stack. Said closing/operating pressure shall be greater than the influent pumping pressure such that closure is maintained on the plate stack containing all fluids within the confines of the peripheral gasket of the spacer plates totally isolating all fluids and internal components from the outside environment. The influent mixing chamber may or may not be connected through the head stock of the supporting frame such that it is in fluid communication with a riser pipe connected by a tee (T). Said riser pipe shall be of higher elevation than the spacer plate stack and shall terminate by means of a pressure regulating device for the purpose of (1) collecting gasses that may be present in an influent fluid so that said gasses may be released preventing said gasses from entering the electrocoagulation device and thus reducing the electrical conductivity of said fluid and (2) providing a passive relief valve that may be set for a selected, maximum operating pressure such that the safe operating pressure of the electrocoagulation device may not be exceeded therefore preventing the release of hazardous and/or non-hazardous fluids and/or material to the outside environment. Said pressure regulating device shall be connected to a conduit that shall return any released fluids to the storage, equalization and/or collection tank or vessel containing the fluid before transfer to the electrocoagulation device. The two effluent conduits that may or may not extend through the head stock of the frame and may or may not be in fluid communication by means of a manifold shall connect to the interconnecting effluent pipe that is in fluid communication with a physical, mechanical, and/or organic separation means and shall be connected to said separation means through a pressure regulating device that maintains pressure on the electrocoagulation device such that gasses may not evolve as a result of electrolysis until pressure on the fluid is released upon entry to the separation device. This is done to (1) keep evolved gasses (O_2 or H_2) in solution so that they are available for oxidation reduction reactions (2) to prevent gas bubbles from reducing the electrical conductivity of the fluid as it flows through the electrocoagulation device and (3) allowing the evolved gasses to be utilized for flotation clarification upon entry to the dissolved air/gas flotation chamber where liquid-liquid and/or liquid-solids separation occurs. When dissolved air/gas flotation is used as the separation means, a riser conduit shall be connected to the effluent conduit before said pressure regulation device by means of a Tee (T) as afore mentioned at the influent riser before entry to the electrocoagulation device. Said effluent riser is utilized as (1) a redundant passive relief valve that can be set at a selected operating pressure such that the safe operating pressure

of the electrocoagulation device is not exceeded preventing the release of fluids and other materials to the outside environment and (2) to accumulate any gasses that may have evolved such that they may be released as not to allow large bubbles to enter into the flotation chamber where they may disrupt proper flotation mechanics.

The afore mentioned physical, mechanical separation device, (dissolved air/gas flotation chamber) may or may not be substituted with other physical, mechanical and/or organic separation means depending on the nature of the fluid, the undesirable matter and/or living organisms present therein, and the desired goals and objectives of treatment. Said physical, mechanical and/or organic separation means are preferably a two phase or three phase decanting centrifuge as used for dewatering of biological sludges and separating oil, water and solids, a membrane concentration system and/or a membrane bioreactor as used for removal of dissolved organic species, hydro cyclones as used for separating selected liquids-solids and liquids-liquids from soil slurries and oil field drilling fluids, a rotary or belt press as used for dewatering of biological sludges and/or a plate and frame filter press as utilized for dewatering of hazardous sludges.

Important features have been broadly presented as to allow a better understanding of the detailed description that follows such that those skilled in the art may appreciate the unique contributions and engineering concepts of the present invention. It shall be understood by those skilled in the art that specific methods and structures described herein may be incorporated into differing designs that may be used to accomplish the same and/or similar objectives. It shall be understood that additional objects, if not set forth specifically herein, will be readily apparent to those skilled in the art from the following detailed description and from the drawings.

ABSTRACT

The present invention introduces method and apparatus comprising an improved design for the high pressure electrocoagulative treatment of aqueous and viscous fluids and sludge. The apparatus is configured as a plate and frame design utilizing hydraulic or screw type mechanical closure on a plurality of recessed, gasketed, non-electrically conductive electrocoagulation spacer plates, hereafter referred to as spacer plates, that completely enclose and isolate all fluids, electrical contacts, and electrodes within the confines of the apparatus. The spacer plates include integral supports on their edges that position and support said spacer plates with enclosed electrodes on top of the side rails of the supporting frame of the apparatus allowing said spacer plates to be separated for electrode replacement and maintenance and conversely closed, pressured and put into service. The apparatus also includes a baffled influent and effluent chamber at both ends for the addition and flash mixing of chemical reagents and/or flocculants and that provide a means of fluid communication between fluid conduits and chambers formed within the apparatus by the interconnection of gasketed ports and cavities located in the spacer plates and external conduits thus allowing fluids to enter and exit the apparatus. Various physical, mechanical and/or organic separation means are utilized determined by influent fluid characteristics and the desired goals and objectives of treatment.

Brief Description of the Drawings:

The preceding features and objects of the present invention and additional objects not listed herein may be clearly understood by those skilled in the art from the detailed description which follows and the drawings in which:

FIG. 1 is a schematic, block flow diagram of the electrocoagulation method of the present invention.

FIG. 2 is four elevated views of the preferred apparatus of the present invention

FIG. 3 is a horizontal cross section of the side view of the preferred apparatus of the present invention.

FIG. 4 is a front and side view of a right single recessed electrocoagulation spacer plate of the preferred apparatus.

FIG. 5 is a front and side view of a left single recessed electrocoagulation spacer plate of the preferred apparatus.

FIG. 6 is a view of an electrode of the preferred apparatus.

FIG. 7 is an isometric and front view of the influent mixing chamber/plate of the preferred apparatus.

FIG. 8 is an isometric and front view of the effluent mixing chamber/plate of the preferred apparatus.

FIG. 9 is a front and side view of a right double recessed electrocoagulation spacer plate of the preferred apparatus.

FIG. 10 is front and side view of a left double recessed electrocoagulation spacer plate of the preferred apparatus.

FIG. 11 is a horizontal cross section of three, single recessed electrocoagulation spacer plates through the line A-A' of FIG. 4 when said spacer plates are closed and held together with pressure.

FIG. 12 is a horizontal cross section of three, double recessed electrocoagulation spacer plates through the line B-B' of FIG. 9 when said spacer plates are closed and held together with pressure.

FIG. 13 is an isometric view of a plurality of electrocoagulation spacer plates of the preferred apparatus shown in a closed position without the supporting frame.

FIG. 14 is an isometric view of an external electrical buss bar attachment of the preferred apparatus.

FIG. 15 is a front and side view of an offset hexagonal electrocoagulation spacer plate of the preferred apparatus.

FIG. 16 is a view of an offset, hexagonal electrode of the preferred apparatus.

We claim:

(1) An apparatus and system that uses an improved design for the high pressure electrocoagulative treatment and subsequent removal of undesirable matter and organisms in suspension, in solution and/or in a stable state of emulsion in aqueous and viscous fluids and sludge comprising:

- A plate and frame design utilizing hydraulic or screw type mechanical closure and pressure on a plurality of recessed, gasketed, non-conductive spacer plates that completely or partially enclose square, rectangular, offset pentagonal and hexagonal or rod shaped electrodes in such a way as to form chambers through which an aqueous and/or viscous fluid may flow and may or may not come into contact with the electrode surfaces and also be exposed to the electromotive force present therein;
- Applying a voltage to said electrodes in such a way on said electrodes to produce an alternating sequence of positive and negative electric potentials and thus causing a continuous flow of electrical current through the aqueous and viscous fluid flowing through said chambers;
- Reacting with undesirable matter and/or organisms present in suspension, in solution and/or in a stable state of emulsion in the aqueous and/or viscous fluid with material sacrificed from the electrode surfaces and/or the electromotive force produced by said applied voltage within the apparatus in such a way as to cause the destabilization of colloidal particulates and/or emulsions, the direct chemical replacement and precipitation of substances, the co-precipitation of substances and/or disrupting the osmotic interchange of fluids through permeable, semi-permeable and/or other membrane boundaries of undesirable living organisms such as bacteria, viruses and/or cysts therefore causing the implosion or explosion of said organisms rendering them harmless to humans, animals, insects, vegetation and/or the environment;
- A physical, mechanical and/or organic separation means in fluid communication with said apparatus via a conduit with a pressure release valve located at the point of entry to the said separation device such that pressure is maintained within the apparatus and the conduit such that any evolved gasses shall be maintained in solution within the apparatus and the conduit such that said non-evolved gases shall be available for oxidation/reduction reactions with matter and/or organisms in solution, in suspension and/or in a stable state of emulsion in the aqueous and/or viscous fluid;
- Said physical, mechanical and /or organic separation means is preferably (1) a dissolved air/gas flotation chamber as utilized for aqueous fluids such as water and wastewater, (2) a two phase and/or three phase decanting centrifuge as utilized for the disinfection (destruction of pathogens) and subsequent dewatering of biological sludge, liquefied manure and/or the separation of oil, water and solids, (3) a membrane concentration system and/or membrane bioreactor as utilized for concentrating and/or elimination of organic substances, (4) hydro

cyclones as utilized for soil slurries and oilfield drilling fluids, (5) a rotary and/or belt press as utilized for dewatering biological sludge and/or (6) a plate and frame filter press as utilized for dewatering of hazardous sludge.

(2) An apparatus and system as recited in claim (1), wherein the hydraulic or otherwise screw type mechanical closure pressure on the recessed, gasketed,, non-conductive spacer plates with electrodes is greater than the influent pumping pressure of the aqueous and/or viscous fluid being pumped through the apparatus such that the apparatus contains all fluids and substances within the confines of the chambers formed by the recessed, gasketed, non-conductive spacer plates;

- Question: Do we need to claim slots at alternating ends of electrode plates such that a serpentine or sinuous path is followed by the fluid?

(3) An apparatus and system as recited in claim (1) wherein the recessed, gasketed, non-conductive spacer plates posses integral supports on the edges such that the spacer plates with enclosed electrodes shall rest on the side rails of a square or rectangular elongated frame and are free to be opened and closed for electrode replacement and/or other maintenance of the apparatus;

(4) An apparatus and system as recited in claim (1) that includes baffled influent and baffled effluent chambers and/or plates at both ends that may or may not be integral with the square or rectangular elongated frame for; <1> the addition and flash mixing of chemical reagents and/or flocculants and <2> also provides a means of fluid communication to an influent and/or effluent conduit that may or may not be within the confines of the gasketed spacer plates for aqueous and/or viscous fluids entering or exiting the apparatus.

(5) An apparatus and/or system as recited in claim (4) wherein the effluent fluid conduit is formed by the interconnection of gasketed ports in the recessed, gasketed, non-conductive spacer plates.

(6) An apparatus and/or system as recited in claim (5) (or claim 1-?) wherein the means of dispersing the electrical current to the electrodes and throughout the apparatus is accomplished by an internal electrical conduit that is formed by metallic inserts embedded within the confines or inserted thru gasketed ports of the recessed, gasketed non-conductive spacer plates in such a way that they contact each other and the enclosed electrodes forming a continuous electrical conduit when closure pressure is applied to a plurality of spacer plates with enclosed electrodes;

(7) An apparatus and/or system as recited in claim (6) (or claim 1) wherein offset, hexagonal electrodes may be larger than the recessed, gasketed, non-conductive spacer plates such that the exposed, edges of the electrodes may be connected to an external, flat buss bar by means of integral, flat clamps that snaps onto and off of the exposed edges of said electrodes thus providing a less expensive, easily maintained configuration that may be used in non-explosive environments;

(8) An apparatus and system as recited in claim (7) wherein the recessed, gasketed, non-conductive spacer plates are in the shape of an offset pentagram and/or hexagram, such that the edges of the larger electrodes may be exposed in such a way as to allow a flat buss bar with integral clamps to snap onto and off of the exposed corners or edges of the electrodes.

(9) An electrocoagulation spacer plate hereby defined as a recessed, gasketed, non-electrically conductive, usually square or offset hexagonally shaped plate of sufficient thickness that may (1) contain a variety of shaped electrodes within a recessed boundary such as to hold and position said electrodes in a specific orientation, (2) contains multiple, integral, gasketed ports that shall align with like gasketed ports in adjacent spacer plates on either side forming internal fluid conduits perpendicular to the vertical axis of said spacer plate when a plurality of said spacer plates are closed and held together, (3) contains multiple, integral, gasketed ports that shall align with like gasketed ports in adjacent spacer plates on either side containing metallic inserts embedded or inserted in said ports, that shall contact other said metallic inserts and/or enclosed electrodes therein forming a continuous electrical conduit perpendicular to the vertical axis of said spacer plate when a plurality of said spacer plates are closed and held together and (4) contains a peripheral gasket near the outer perimeter of said spacer plate that surrounds and contains all enclosed electrodes and all enclosed, gasketed fluid and electrical conduits within the confines of said spacer plate when a plurality of said spacer plates are closed and held together therefore isolating said electrodes, fluid conduits, electrical conduits, fluids and other matter and substances from the outside environment. Said electrocoagulation spacer plates may or may not be recessed and gasketed on one and/or both sides and have slotted, positioning supports integral to the edges that rest on the side rails of a square and/or rectangular, elongated frame.

Description of the Preferred Embodiment

Referring to FIG. 1, fluids 110 collected in tank 100 are pumped through an interconnecting influent pipe 116 by means of a pump 115 to the high pressure, plate frame electrocoagulation apparatus 140. An actuated valve 125 is located in the interconnecting influent pipe 116 to contain fluids 110 in the collection tank 100 when the system is not in operation. Pump 115 is typically a centrifugal pump for low viscosity fluids and/or a progressive cavity pump for high viscosity fluids, slurries and/or sludge and is capable of variable flow rates and high pressures (10 to 225 psi). A riser pipe 138 is connected to the interconnecting influent pipe 116 at a higher elevation than the electrocoagulation apparatus 140 to collect any undissolved gas that may be present in the fluid 110 and venting said gas through pressure regulator valve 139 preventing any undissolved gas from entering the electrocoagulation apparatus 140. Gases are resistive to electrical current and reduce the electrical conductivity of influent fluids 110 inhibiting treatment. Pressure regulator valve 139 also provides passive pressure release in the event that unsafe pressures are encountered. Influent pressure of the fluid 110 is monitored by the pressure sensor 135 which transmits a variable signal proportional to said pressure to the controller 130. The controller may be a computerized PLC and/or other configured system utilizing analog and discreet inputs and outputs for data logging and activating automated devices. Two injection ports 126 are connected to the interconnecting influent pipe 116 for the addition of chemical reagents for

desired oxidation reduction reactions and pressurized air for evacuating fluids from the electrocoagulation apparatus 140 when maintenance is required.

The electrocoagulation apparatus 140 is connected to a power supply 145 that provides an applied voltage to said apparatus. The applied voltage may be an alternating, direct and/or a pulsed current. For the purposes of this discussion, the applied voltage shall be described as a direct current and voltage applied to the terminal connections 128 of the electorcoagulation apparatus 140. As the pressured fluid 110 flows through the electrocoagulation apparatus 140 various reactions occur as described in our co-pending U.S. Patent application Ser. No. 60/244,615 and in the forthcoming details. As the pressurized fluids 110 exit the electrocoagulation apparatus 140, a preferred but not essential method step is the injection of a flocculent aid via injection port 127 to assist with subsequent separation methods. Pressurized fluids 110 exit the electrocoagulation apparatus 140 by means of the interconnecting effluent pipe 117 with attached temperature sensor 137 which monitors the temperature of the effluent fluids 110 and transmits a variable signal proportional to the temperature to the controller 130. The interconnecting pipe 117 is connected to an actuated pressure regulator valve 154 by raiser pipe 153 such that the elevation of the riser pipe 153 is higher than the electrocoagulation apparatus 140 and the subsequent separation means 150 and collects any undissolved gases that may be present in the pressurized fluid 110 and periodically purges said gases from the system to ensure that no undissolved gases enter the subsequent separation means 150. The pressure regulator valve 154 also provides passive pressure relief in the event that unsafe pressures are encountered.

Pressure of the effluent pressurized fluid 110 is monitored by the pressure sensor 136 which transmits a variable signal proportional to said pressure to the controller 130. The pressurized fluid 110 may enter a variety of physical, mechanical and/or organic separation means 150 through pressure regulator valve 152 and pressure on the fluid 110 is dissipated as separation occurs by flotation, sedimentation, filtration and/or centrifugal force depending on the mechanism of the physical, mechanical and/or organic separation means 150. Treated fluid 110 exits the separation means 150 by means of a fluid conduit or pipe 118 connected to said separation means 150 by actuated valve 200. Separated materials removed from the fluids 110 are collected in a holding vessel 159 for further disposition by a transfer pump 160.

FIG. 2 and FIG. 3 show four elevated views of the high pressure plate and frame electrocoagulation apparatus 140 of the present invention. Together with FIG. 4, a horizontal cross section through the Z-axis viewing from the front of the head stock 122, details of the structure of the supporting frame become apparent to those skilled in the art. The supporting frame of the preferred apparatus comprises a rectangular, solid steel head stock 122 and tail stock 124 welded to two, heavy duty rectangular steel tubing side rails 142 perpendicular to said head stock 122 and tail stock 124 forming an elongate frame above grade for supporting, positioning and holding closure pressure on a plurality of electrocoagulation spacer plates 300 hereafter refereed to as ES P's (ESP's are defined in the objects of the present invention and shall be discussed in detail in the forthcoming text). The ESP's 300 ride on the top of the side rails 142 of the supporting frame and may be separated or opened for accessing internal components and subsequently closed and pressured by

the hydraulic closure mechanism 144 that is integrally attached to the tail stock 124 and the push plate 146. The push plate 146 also rides on top of the side rails 142 and is held in a perpendicular position by two rollers 148. A spool piece 147 may or may not be included to allow for future expansion, different configurations of the apparatus and/or incorporation of multiple power supplies by segregating groups of ESP's 300.

The head stock 122 of the preferred apparatus is constructed of solid steel providing a supporting leg for the apparatus and a means for attachment of the two side rails 142. Electrical contact terminals 128 are inserted through two ports 311 near the top of the head stock 122 providing a means for the applied voltage supplied by the power supply 145 to contact internal components. The external electrical contact utilizes standard explosion proof conduit-junctions that are familiar to those skilled in the art. Two through wall ports 121 are located near the bottom corners of the head stock 122 and are in fluid communication with internal, effluent conduits 149 providing a means for fluids 110 to exit the apparatus. Although only two effluent ports 121 are shown, more may be utilized determined by the application. The two effluent ports 121 are connected to an effluent manifold 123 which is in fluid communication with the interconnecting effluent pipe 117. Effluent temperature sensor 137 and effluent pressure sensor 136 are located in the interconnecting effluent pipe 117 to monitor temperature and pressure of the pressurized fluid 110 as it exits the apparatus and transmit variable signals proportional to the temperature and pressure to the controller 130. The interconnecting influent pipe 116 is in fluid communication with the influent feed

pump 115 (FIG. 1) and incorporates actuated valve 125 used for segregating the system from the collection tank 100 and allowing the apparatus to be depressurized by opening pressure regulator valve 139 and/or pressure regulator valves 154 and 152 (FIG. 1). Integral with the influent interconnecting pipe 116 are two injection ports 126 for the addition of chemical reagents that may or may not be utilized for oxidation reduction and/or other desired reactions, and air for blowing down the apparatus to evacuated fluids 110 from the apparatus prior to or during depressurization and subsequent opening for inspection and maintenances. A riser pipe 138 is connected to the influent interconnecting pipe 116 behind the injection ports 126 and before the influent conduit 325 through the head stock 122 providing a means of collecting any gases not in solution and purging said gases to the collection tank 100 to avoid inclusion of said gases in the influent pressurized fluid 110 avoiding a reduction of electrical conductivity in the influent fluid 110. Integral with the riser pipe 138 are pressure regulator valve 139 and influent pressure sensor 135 which monitors influent fluid 110 pressure and transmits a variable signal proportional to said pressure to the controller 130. Pressure regulator valve 139 also provides passive pressure relief by receiving a signal from the controller 130 to open when a pre-set, limiting pressure is detected thereby avoiding an unsafe condition.

The tail stock 124, like the head stock 122, also provides a support leg for the apparatus and a means of welded attachment for the two side rails 142. The tail stock 124 also provides a means of supporting the integrally attached hydraulic closure mechanism 144 for opening, closing and maintaining pressure on the closed

stack of ESP's 300. The hydraulic closure mechanism 144 is an air operated closure mechanism lockable in the closed position that is capable of maintaining sufficient closure pressure to allow influent pumping and operating pressure of the fluid 110 at 110 psi. Closure pressure is directly correlatable to the cross sectional surface area of the ESP 300 stack and will vary with the size of the preferred apparatus. All hydraulic components and a local control panel 220 are integral with and enclosed within the tail stock 124 and include pneumatic and hydraulic pressure relief bypass means (not shown) to avoid damage to the apparatus in a malfunction condition. All integral, internal hydraulic components, air headers, pumps, air regulators etc. are accessible to the operator through an access door 143 in the tail stock 124.

FIG. 5, 6, 10, and 16 show front and side views of ESP's of the preferred apparatus and together with FIG. 14, an isometric and cross-sectional view of a plurality of ESP's shown in a closed position without the supporting frame, and FIG. 7 and 17, views of electrodes 141 of the preferred apparatus, the mechanism of fluid 110 transport through the apparatus and distribution of the applied voltage throughout the apparatus will become apparent.

ELECTROCOAGULATION SPACER PLATES (300), hereafter referred to as ESP's, are defined as flat, recessed, gasketed, ported devices constructed of non-electrically conductive materials comprising an internal cavity 305 for supporting and containing various shaped electrodes 141 within confined boundaries such that when a plurality of like devices is stacked together, an internal, elongate cavity 221 with multiple, parallel tubular conduits is isolated within. ESP's are typically square and/or offset hexagonally shaped. FIG. 14 is an isometric view of a plurality of

ESP's 300 stacked together without a supporting frame or electrodes 141 showing the internal elongate cavity 221 and surrounding parallel conduits 222 within. When flat, ported electrodes 141 are enclosed within the recessed boundaries 224 of the closed ESP's 300, a plurality of perpendicular chambers 223 is isolated within the internal, elongate cavity 221 such that fluids 110 may flow through a path dictated by the shape and location of any openings in the flat, enclosed electrodes 141. In this illustration the preferred shape and location of said openings are rectangular ports 226 located at alternating ends therefore dictating a meandering or sinuous path. Said ports may be circular, rectangular, etc. and may be located at alternating tops and bottoms of electrodes 141, at alternating right and left sides of electrodes 141 and/or any combination of said locations as to dictate a meandering or sinuous flow pattern and/or a spiral or conical flow pattern. When an applied voltage is connected to the terminals 128 of the apparatus and distributed throughout the apparatus such that alternating positive (+) and negative (-) electric potentials are realized by the enclosed electrodes 141 while fluids 110 are flowing through the dictated sinuous path, an electric current flows from electrode 141 to electrode 141 and therefore through the pressurized fluid 110 circulating through the apparatus.

The means of distributing the applied voltage throughout the apparatus is accomplished by interconnecting, metallic inserts 310 that are embedded and/or inserted in the upper, gasketed ports 301 of the ESP's such that when a plurality of ESP's 300 are closed and held together said metallic inserts 310 contact each other, the power contact 303 of selected electrodes 141, and the electrical terminal contacts

128 located at the head stock 122, thereby defining a continuous electrical conduit (FIG.4/312) and a complete circuit for distribution of electrical power. All ports 301 & 304 within the body of the ESP's 300 are individually contained by port gaskets 302 that are inserted into grooved recesses such as to hold said port gaskets 302 in place and seal said ports 301 and 304 containing and isolating same from fluid intrusion as with upper electrical ports 301 and/or fluid extrusion as with the case of the lower fluid ports 304 used for effluent fluid conduits 149 (FIG. 4) formed when a plurality of ESP's are closed and held together. A peripheral gasket 307 is positioned within a like recessed groove located around the outer perimeter of the ESP's 300 thereby containing all internal cavities 305, all gasketed ports used for electrical purposes 301, metallic inserts used for electrical conduits 310, all gasketed ports used as fluid conduits 304, and pressured fluids 110 within the confines of said peripheral gasket 307 and ESP's 300 isolating same from the outside environment. ESP's may or may not be single recessed FIG. 5 and FIG. 6 meaning that the internal recessed boundary support 224 with rectangular recession 306 for location of selected electrode power contact 303, is located on only one surface for enclosing and positioning of one electrode 141 and/or double recessed FIG. 10 and meaning that the ESP's 300 contain internal recessed boundary supports 224 on both surfaces for enclosing and positioning of two electrodes 141. A double recessed ESP 300 may be utilized with one powered electrode 141, using the second recessed boundary support 224 to position a non-powered baffle surface creating a longer fluid path within the apparatus for (1) increasing the dwell time (reaction time) that the fluid 110 being treated is exposed to the electromotive force present within the

apparatus and (2) increasing the distance between powered electrodes 141 requiring a higher applied voltage resulting in increased electrolysis and increased release of oxygen (O_2) and hydroxyl (OH^-) ions available in solution for oxidation reduction reactions. When a non-powered baffle plate is incorporated in the second recessed boundary support 224 of a double recessed ESP 300, said baffle plate is held in position by pins 315, inserted parallel to the outer surface of said baffle plate and perpendicular to the recessed boundary support 224 edge (FIG. 10). The extended, rectangular recession 306 that is integral with the internal recessed boundary support 224 for contacting selected electrodes 141 may be located in the right position as shown in FIG. 5 or in the left position as show in FIG. 6 to receive the electrode power contact 303 of selected electrodes 141. ESP's 300 rest vertically within the two side rails 142 of the supporting frame by means of a slotted, integral support 308 using the rectangular shaped slot 309 for positioning and alignment on the rectangular tubing of said side rails 142.

FIG. 8 is an isometric and front view of an influent mixing chamber plate 320 (the isometric view omits integral supports) that may or may not be attached to the head stock 122. It is comprised of many like features in that there are two upper gasketed ports 301 used to contain metallic inserts 310 and two, lower gasketed ports 304 used for fluid transport, but this device does not contain and position any electrodes 141. The influent mixing chamber plate 320 has a centrally located influent conduit 325 that protrudes through the influent port 151 in the head stock 122 and is in fluid communication with the interconnecting influent pipe 116 thereby allowing pressurized fluids 110 to enter the apparatus. It is a hollow

structure with internal baffles 321 oriented such that the fluid 110 direction is reversed when traversing through the chamber, agitating said fluid 110 to mix any chemical reagents that may be injected via the injection ports 126 in the interconnecting influent pipe 116. There is a rectangular port 322 located at the bottom of the back wall 323 to allow the pressurized fluid 110 to flow through. All tubular ports 301 and 304 extend from the front wall 324 to the back wall 323 isolating same from the internal chamber between. The influent mixing chamber plate 320 is constructed of non-electrically conductive materials and isolates electrical contact with the head stock 122 and side rails 142 like ESP's 300.

FIG. 9 is an isometric and front view of the effluent mixing chamber plate 330 (the isometric view is shown without integral supports). It is so named because it receives fluid flow through the influent, rectangular port 335 located on the upper portion of the front surface 331 and redirects fluid flow to the head stock 122 of the apparatus via the two gasketed fluid ports 304 located at the bottom inside surface 331. The lower, gasketed, fluid ports 304 align with like gasketed ports 304 in adjacent chambers thereby comprising a continuous fluid conduit 149 (FIG. 4) within confined boundaries isolated from the outside environment. An injection port 127 is located at one side where fluid flow is reversed by one of two internal baffles 332 for injection and flash mixing of a flocculent aid and/or chemical reagents. The back surface 333 of the effluent mixing chamber plate 330 is contacted by the push plate 146 which is connected to the hydraulic closure mechanism 144 providing closure pressure for the apparatus. Like the influent mixing chamber plate 320, the effluent mixing chamber plate 330 contains no

electrode 141. Its purpose is to redirect fluid flow to the head stock 122, provide an injection means 127 for flocculent and/or chemical reagents and mix same via internal baffles 332, provide a means of contact to the push plate 146 and provide a means of electrical insulation to the supporting frame.

Therefore it is an object of the present invention to provide a new and improved electrocoagulation method and apparatus for the high pressure treatment of aqueous and/or viscous fluids while containing all fluids, fluid conduits, and electrical conduits within the boundaries of said apparatus isolating said fluids and conduits from the outside environment.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus that is easily manufactured with a means of easily accessing internal and external components for electrode replacement and other maintenance.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus that incorporates best engineering practices thus establishing process and equipment confidence and acceptability for access to a variety of applications, markets and environments.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus incorporating a plate and frame design construction that is easily manufactured and easily maintained.

It is another object of the present invention to provide a new and improved electrocoagulation spacer plate design that (1) is constructed of a non-electrically conductive material and shall contain various shaped electrodes within a recessed boundary such as to hold and position said electrodes in a specific orientation (2) contains integral, gasketed ports that shall align with like gasketed ports in adjacent spacer plates forming internal fluid conduits when a plurality of said spacer plates are closed and held together (3) contains integral, gasketed ports that shall align with like gasketed ports in adjacent spacer plates such that when metallic inserts are embedded or inserted in said ports, said metallic inserts shall form an internal electrical conduit when a plurality of said spacer plates are closed and held together and (4) contains a peripheral gasket near the outer perimeter of said spacer plates such that when a plurality of said spacer plates are closed and held together said peripheral gasket surrounds and contains all enclosed electrodes, all enclosed, gasketed fluid and electrical conduits and all fluids therefore containing and isolating same from the outside environment.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation apparatus comprising an elongated, square, rectangular frame for supporting a plurality of spacer plates with enclosed electrodes and conduits having an integral hydraulic means for applying and releasing closure pressure on said plurality of spacer plates allowing the apparatus to be easily opened for maintenance and subsequently, easily closed with sufficient pressure to ensure containment and isolation of all fluids and conduits within the confines of the apparatus.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus to provide an influent and effluent chamber for reagent mixing and directing fluid flow to allow all plumbing to be located at one end of the apparatus and to allow said hydraulic/ mechanical closure means to be located at the opposite end of the apparatus.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus that provides a variety of physical, mechanical and/or organic separation means to subsequently remove materials, said

separating means shall be determined by the application, influent characteristics and goals of treatment.

It is another object of the present invention to provide an alternate, less expensive electrocoagulation apparatus comprising an external electrical conduit with integral attachment means for attachment to the electrodes for applications in a non-hazardous environment (ie. non-explosion proof).

It is another objective of the present invention to provide an alternate, less expensive electrocoagulation apparatus comprising external fluid conduits in fluid communication with the influent and effluent mixing chambers of the apparatus via an external manifold.

It is another object of the present invention to provide a new and improved high pressure electrocoagulation apparatus that incorporates the four mechanisms of disinfection and in so doing satisfies the requirements of a process to further reduce pathogens (PFRP).

Exhibit 7

Lindquist, Terrie

From:	Rhebergen, Constance
Sent:	Wednesday, October 09, 2002 5:38 PM
To:	gus.ecolotron@ev1.net
Subject:	Provisional Patent Application Draft
Attachments:	ECOLOTRO.doc

ECOLOTRO.doc
(104 KB)

Gus,

Attached is a red-lined version of the provisional patent application. I have started from the section you provided, re-formatted and modified. The red-lines are intended to show you the general modifications. The claims will not be modified at this time as they are not examined. I will also add the description for the last 4 drawings tomorrow. Please provide the names of all inventors, including middle initials. Please provide residential addresses for all inventors. Also, we need to discuss the arrangements regarding type of assignment to Ecolotron prior to filing the application.

Thank you.

Yours very truly,

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Date of Deposit: ____________ By: Sharanda Mozart ____________

HIGH PRESSURE PROCESS AND APPARATUS FOR THE ELECTROCOAGULATIVE TREATMENT OF AQUEOUS AND VISCOUS FLUIDS

PROVISIONAL PATENT APPLICATION

Inventors: Tom Gus Gavrel Docket No.: 0271KR.044551

Assignee: Ecolotron, Inc.

Background of the Invention

Field of the Invention

~~[0001]~~The present invention relates to a high pressure method and apparatus for the treatment of aqueous ~~and~~ or viscous fluids ~~by means of flowing through a plurality of electrically charged electrodes therefore~~ to destroy~~ing~~ or otherwise render~~ing~~ harmless ~~any~~ undesirable living organisms in the fluids. A method and apparatus for removal of ~~and allowing any~~ undesirable matter ~~present therein to be~~ subsequent~~ly removed such that once~~ to treated~~d~~ment is included.~~, the fluids may be classified as harmless or otherwise acceptable to humans, animals, insects, vegetation and the environment~~. ~~The invention also relates to a plate and frame apparatus utilizing recessed, gasketed, non-conductive spacer plates with enclosed, exchangeable electrodes of various designs that are suspended on a supporting, square, elongate frame in such a way as to allow the spacer plates with electrodes to be easily separated or opened to exchange the electrodes or perform other maintenance and subsequently closed and pressured utilizing a hydraulic or screw type mechanical closure device that shall maintain sufficient closure/operating pressure to seal the plurality of said spacer plates with enclosed electrodes~~

~~therefore containing pressured fluids within the confines of the plurality of chambers formed therein. The apparatus incorporates influent and effluent mixing chambers (containing injection ports for chemical reagents) in fluid communication with conduits that may or may not be within the confines of said spacer plates and interconnecting influent and effluent piping allowing fluids to enter and exit the apparatus. Multiple mechanical separation means in fluid communication with the apparatus are used to subsequently separate liquids from liquids, liquids from solids and/or for dewatering of the fluid.~~

[0001] Description of the Related Art

[0002] Various methods and apparatus are currently used ~~The present invention is directed to improving methods and apparatuses~~ for the treatment and/or removal of undesirable matter and~~/or~~ organisms present in solution, in suspension ~~and~~/or in a stable state of emulsion in aqueous fluids such that ~~said~~the methods and apparatuses may process ~~said~~the fluids at increased flow rates and also may process ~~said~~ fluids having high viscosities (biological sludge, soil slurries, oil field drilling fluids, etc.) in an environmentally safe, economical, user friendly, easily manufactured and easily maintained manner. Specific~~Many~~ electrocoagulative treatment methods and apparatuses have been described in the literature. An example is Lacomme, 1901. [Gus, please provide the full cite and a copy of this reference so that we can determine if it is pertinent.] ~~dating as far back at 1901, Lacomme. The present invention incorporates unique engineering concepts that shall be apparent to those skilled in the art. Previous attempts to achieve engineering excellence are described in the forthcoming list of prior inventions and patents.~~

[0003] U.S. Patent No. 3,969,245~~, 7/1976~~ issued to Ramirez discloses an electorcoagulation method and apparatus utilizing a cylindrical cell with concentrically positioned electrodes for electrolitically generating large quantities of gas bubbles while simultaneously flowing wastewater through the cell to form an embryo floc. The embryo floc~~ which~~ subsequently attaches to the gas bubbles to achieve clarification by floatation. Ramirez vents~~ed~~ the electrocoagulation cell to the atmosphere to avoid build up of pressure within the cell. One shortcoming of the Ramirez teaching is that c~~C~~urrent environmental standards dictate that fugitive air emissions are unacceptable and present complex permitting issues. Venting to atmosphere also limits applications in which an apparatus or process may be implemented due to hazardous materials venting to atmosphere and risk of explosion.

[0004] U.S. Patent No. 5,928,493~~, 7/1999~~ issued to Morkovsky, et. al. relates to an electrocoagulation process and system for low pressure and low flow sterlization ~~conditions~~ incorporating an agitated defoam tank utilized for allowing entrained ~~gasses~~gases to escape prior to entering a settling clarifier. The requirement~~inclusion~~ of a defoam tank increases the overall footprint of the apparatus, adds additional plumbing and mixing components and vents off ~~gasses~~gases to atmosphere. ~~For the afore mentioned reasons, t~~This is unacceptable in many applications. The reactor cell housing of Morkowsky ~~with~~includes opposed grooved sides for retaining the electrode plates. This limits the application to low pressure conditions.~~ also presents problems.~~ Because of the spacing of the plates, when fluid velocities reach a critical point the differential pressure through the reactor cell is too great and the reactor cell is susceptible to leaking creating house keeping issues, exposure of possible hazardous materials to workers and the environment and the release of off gases to the environment. The~~is~~ Morkowsky reactor cell design is mechanically complex~~also~~ depend~~s~~ing on "links" which are a means of

connecting electrical power to the electrodes. These "links" must be inserted between the closely spaced electrode plates and tightened by means of nuts, screws and/or bolts and becomes maintenance intensive when exchanging the electrode plates or performing other maintenance.

[0005] German Patent Document DE 3641365 A1, issued to Klose discusses an electroflotation device for purification and treatment of polluted water by flowing the water over bundles of iron and aluminum electrode plates. Electroflotation is described as a combination of chemical and physical actions whereby iron and aluminum are sacrificed from the anodes and (as with chemical precipitation), utilized as an oxide for flocculation. Electrolytic action between anodes and cathodes release oxygen ~~gasses~~gases in the form of fine bubbles which enter into oxidation reduction reactions with substances in the water causing the precipitation of pollutants. Disinfection, metal~~s~~ removal and oil-~~-~~water emulsion splitting occurs and contaminants are removed by vacuuming floated material from the surface and removing bottom sediments via the sloped bottom of the vessel. This device utilizes a rectangular tank, again open to the atmosphere, non-pressured and is not applicable to viscous fluids or sludges.

~~[0007]~~As illustrated by the background of the invention, attempts to develop methods and devices for the removal of contaminants from fluids have focused on low pressure electrolytic devices.~~shall continue in the future as in the past.~~ It would be advantageous for an apparatus to accommodate high pressure and/or high flow during the treatment process of the sludge or other viscous materials. ~~There has been no effort thus far that provides the benefits, advantages and unique engineering concepts as the present invention. The present invention is considerably unique in comparison~~ It would be advantageous ~~to conventional engineering concepts and in doing so offers a means of~~to caus~~ing~~e undesirable matter to precipitate or co-precipitate from suspension and/or solution, ~~the~~ destabiliz~~ation of~~e suspended colloidal material, ~~the~~

destabilize~~ation of~~ emulsions, or~~and the~~ disrupt~~ion of~~ undesirable living organisms to treat fluid. It would be advantageous to use ~~utilizing distinctively unique recessed, gasketed, non-conductive~~ spacer plates to enclose and hold ~~in a place~~ a variety of shaped electrodes while containing all fluids, electrical conduits and fluid conduits separately~~made up of interconnecting ports sealed by gaskets and capable of operating at high pressures such that viscous fluids may be pumped through the apparatus.~~ It would also be advantageous for an apparatus to contain ~~Additionally, the uniqueness of the apparatus contains~~ integral mixing chambers. A hydraulic mechanical closure means would also be advantageous. ~~and supporting frame utilizing a hydraulic mechanical closure means allowing ease of maintenance, cleaning, and operator safety.~~

[0006] ~~Therefore it is an object of the present invention to provide a new and improved electrocoagulation method and apparatus for the~~ It would be advantageous to allow high pressure treatment of aqueous and/or viscous fluids while containing all fluids, fluid conduits, and electrical conduits within the boundaries of ~~said~~an apparatus isolating ~~said~~the fluids and conduits from the outside environment.

~~[0009]It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus that is easily manufactured with a means of easily accessing internal and external components for electrode replacement and other maintenance.~~

~~[0010]It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus that incorporates best engineering practices thus establishing process and equipment confidence and acceptability for access to a variety of applications, markets and environments.~~

~~[0011]It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus incorporating a plate and frame design construction that is easily manufactured and easily maintained.~~

~~[0012]It is another object of the present invention to provide a new and improved electrocoagulation spacer plate design that (1) is constructed of a non-electrically conductive material and shall contain various shaped electrodes within a recessed boundary such as to hold and position said electrodes in a specific orientation (2) contains integral, gasketed ports that shall align with like gasketed ports in adjacent spacer plates forming internal fluid conduits when a plurality of said spacer plates are closed and held together (3) contains integral, gasketed ports that shall align with like gasketed ports in adjacent spacer plates such that when metallic inserts are embedded or inserted in said ports, said metallic inserts shall form an internal electrical conduit when a plurality of said spacer plates are closed and held together and (4) contains a peripheral gasket near the outer perimeter of said spacer plates such that when a plurality of said spacer plates are closed and held together said peripheral gasket surrounds and contains all enclosed electrodes, all enclosed, gasketed fluid and electrical conduits and all fluids therefore containing and isolating same from the outside environment.~~

[0007] ~~It is another object of the present invention to provide a new and improved high pressure electrocoagulation apparatus comprising an elongated, square, rectangular frame for supporting a plurality of spacer plates with enclosed electrodes and conduits having an integral hydraulic means for applying and releasing closure pressure on said plurality of spacer plates allowing the apparatus to be easily opened for maintenance and subsequently, easily closed with sufficient pressure to ensure containment and isolation of all fluids and conduits within the confines of the apparatus.~~

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~~**[0014]**It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus to provide an influent and effluent chamber for reagent mixing and directing fluid flow to allow all plumbing to be located at one end of the apparatus and to allow said hydraulic/ mechanical closure means to be located at the opposite end of the apparatus.~~

~~**[0015]** It is another object of the present invention to provide a new and improved high pressure electrocoagulation method and apparatus that provides a variety of physical, mechanical and/or organic separation means to subsequently remove materials, said separating means shall be determined by the application, influent characteristics and goals of treatment.~~

~~**[0016]**It is another object of the present invention to provide an alternate, less expensive electrocoagulation apparatus comprising an external electrical conduit with integral attachment means for attachment to the electrodes for applications in a non-hazardous environment (ie. non-explosion proof).~~

~~**[0017]**It is another objective of the present invention to provide an alternate, less expensive electrocoagulation apparatus comprising external fluid conduits in fluid communication with the influent and effluent mixing chambers of the apparatus via an external manifold.~~

~~**[0018]**It is another object of the present invention to provide a new and improved high pressure electrocoagulation apparatus that incorporates the four mechanisms of disinfection and in so doing satisfies the requirements of a process to further reduce pathogens (PFRP).~~

Summary of the Invention

~~[0018]~~[0008] The present invention relates to an apparatus and method for treating aqueous and viscous fluids at high pressures including~~comprising:~~ a pump for transferring various fluids ~~through an electrocoagulation device~~, a high pressure plate and frame electrocoagulation device, an effluent conduit in fluid communication with the electrocoagulation device incorporating a pressure regulation device and a physical, mechanical, and/or organic separation means connected to the~~said~~ effluent conduit before or after the pressure regulation device such that the pressure of the aqueous and/or viscous fluid may ~~or may not~~ be controlled~~released~~ through the physical, mechanical and/or organic separation means.

[0009] The high pressure plate and frame electrocoagulation device of a preferred embodiment of the present invention ~~consists~~includes ~~of~~ a plurality of recessed, gasketed, non-electrically conductive spacer plates, hereafter referred to as spacer plates, with integral supports on the edges that contain various shaped electrodes within the recessed boundaries of the spacer plates. The spacer plate holds and positions the electrodes in a specific orientation. The integral supports on the edges of the spacer plates accommodate resting on the side rails of an~~a square or rectangular,~~ elongated frame, preferably square or rectangular. The spacer plate stack can be arranged in various orientations, such as substantially horizontal or substantially vertical. ~~that is supported above grade by legs such that the spacer plate stack is arranged in a horizontal orientation. This in no way implies that the spacer plate stack cannot be oriented in a vertical direction and in many applications it is favorable to orient the spacer plate stack in a vertical direction.~~ In a preferred embodiment, t~~T~~he electrodes can~~may or may not~~ act as a ~~be made of~~ sacrificial material, including iron or aluminum, such that the electrode material will be sacrificed at the anodes in accordance with Faraday's Law when a voltage is applied to ~~said~~the

electrodes. In an alternate preferred embodiment, it is advantageous to include electrodes of ~~However, it may be beneficial to make the electrodes of a~~ non-sacrificial material and/or electrodes coated~~coating said electrodes~~ with a non-sacrificial material. This can be particularly beneficial when the desired effect is oxidation and reduction or organism/organic destruction by the electromotive force present within the device. In a preferred embodiment, the electrodes are slotted, perforated, pierced, or crimped. The electrodes can be constructed of a porous, permeable or semi-permeable material. Other characteristics of electrodes known in the art can be used. Another preferred embodiment of the present invention includes an external electrical conduit with integral attachment means for attachment to the electrodes for applications in a non-hazardous environment (ie. non-explosion proof).

[0010] In one preferred embodiment, the spacer plates are constructed with gasketed ports. These gasketed ports align with each other when a plurality of spacer plates are arranged beside each other such that the gasketed ports create an interconnected channel forming conduits for fluid flow within the confines of an outer gasket located near the peripheral edge of the spacer plates. The aligned gaskets are referred to jointly as the peripheral gasket. The peripheral gasket of the spacer plates contains all fluids, conduits and electrodes such that when the spacer plates are aligned for operation, each conduit is substantially isolated from the outside environment. In a preferred embodiment, the spacer plates are aligned by applying closing or operating pressure to the spacers, preferably by hydraulic mechanical closure means. The integral hydraulic mechanical closure means allows for applying and releasing closure pressure on the plurality of spacer plates allowing the apparatus to be easily opened for maintenance and subsequently, easily closed with sufficient pressure to ensure containment and isolation of all fluids and conduits within the confines of the apparatus. Another preferred embodiment includes external

fluid conduits in fluid communication with the influent and effluent mixing chambers of the apparatus via an external manifold.

[0011] The spacer plates also include an electrically conductive material embedded or attached to the spacer plates. The electrically conductive material is preferably metallic discs, rods, inserts that interact with the gasketed ports. In this manner, when a plurality of spacer plates are pressed together under pressure, an electrical conduit is formed when a voltage is applied and distributed through the interconnecting electrically conductive materials throughout the apparatus and contacting the selected enclosed electrodes. The electrical conduits are within the confines of the peripheral gasket such that upon closure of the spacer plates the electrical conduits are substantially isolated from the outside environment.

[0012] A preferred embodiment of the electrocoagulation device includes a baffled influent and effluent mixing chamber at each end of the spacer plate stack for the addition and mixing of chemical reagents and/or flocculants. This also advantageously provides a means of fluid communication between fluid conduits formed within the apparatus, such as the conduit formed by the interconnecting ports and a center conduit formed by the plurality of cavities of the spacer plates as well as the interconnecting piping allowing fluids to enter and exit the device. This arrangement has the advantage of allowing for influent and effluent plumbing to be located on one end of the device while the hydraulic mechanical closure means can be located on the opposite end of the device to provide closing or operating pressure applied to the spacer plate stack. The closing or operating pressure is advantageously greater than the influent pumping pressure such that closure is maintained on the plate stack containing all fluids within the confines of the peripheral gasket of the spacer plates. In a preferred embodiment, the influent mixing chamber is advantageously connected through the head stock of the supporting frame

such that the head stock is in fluid communication with a riser pipe connected by a tee (T). The riser pipe is advantageously of higher elevation than the spacer plate stack and terminates by means of a pressure regulating device. The pressure regulating device can advantageously provide multiple functions when desired. The pressure regulating device collects gases that are present in an influent fluid so that that gases can be released thereby preventing the gases from entering the electrocoagulation device where they could act to reduce the electrical conductivity of the fluid. Moreover, the pressure regulating device can operate as a passive relief valve that is set for a selected, maximum operating pressure such that the safe operating pressure of the electrocoagulation device is not exceeded therefore preventing the release of hazardous and/or non-hazardous fluids and/or material to the outside environment. In one preferred embodiment, the pressure regulating device is connected to a conduit that returns any released fluids to the storage, equalization and/or collection tank or vessel containing the fluid before transfer to the electrocoagulation device. The two effluent conduits connect to the interconnecting effluent pipe that is in fluid communication with a separation means and connect to the separation means through the pressure regulating device. The pressure regulating device maintains pressure on the electrocoagulation device such that the evolution of gases is inhibited as a result of electrolysis until pressure on the fluid is released upon entry to the separation device. Advantageously, the effect of the pressure regulation is that the released gases that will evolve, such as O2 and H2, are maintained in solution where they are available for oxidation reduction reactions. The inhibition of gas evolution also prevents gas bubbles from reducing the electrical conductivity of the fluid as it flows through the electrocoagulation device. Additionally, the inhibition of gas evolution allows the evolved gases to be utilized for flotation clarification upon entry to the dissolved air/gas flotation chamber where liquid-liquid and/or liquid-solids separation occurs.

When dissolved air/gas flotation is used as the separation means, a riser conduit can be connected to the effluent conduit before the pressure regulation device by means of a Tee (T) the influent riser before entry to the electrocoagulation device. The effluent riser can act as (1) a redundant passive relief valve that can be set at a selected operating pressure such that the safe operating pressure of the electrocoagulation device is not exceeded preventing the release of fluids and other materials to the outside environment and (2) to accumulate any gases that may have evolved such that they may be released as not to allow large bubbles to enter into the flotation chamber where they may disrupt proper flotation mechanics. Other advantageous will be apparent to those with ordinary skill in the art.

~~[0020]~~[0013] Examples of ~~The afore mentioned~~ physical~~,~~ or mechanical separation device useful in various embodiments of the invention include~~, (~~dissolved air/gas flotation chambers,~~)~~ ~~may or may not be substituted with~~ or other separators utilizing physical, mechanical ~~and~~/or organic separation means. ~~depending on the nature of the fluid, the undesirable matter and/or living organisms present therein, and the desired goals and objectives of treatment. Said~~ A preferred embodiment of the ~~physical, mechanical and/or organic~~ separation means ~~are~~includes ~~preferably~~ a two phase or three phase decanting centrifuge as used for dewatering of biological sludges and separating oil/~~,~~water/~~ and~~ solids, a membrane concentration system, ~~and/or~~ a membrane bioreactor as used for removal of dissolved organic species, a hydro cyclones as used for separating selected liquids-solids and liquids-liquids from soil slurries and oil field drilling fluids, a rotary or belt press as used for dewatering of biological sludges ~~and/~~or a plate and frame filter press as utilized for dewatering of hazardous sludges.

~~[0021]~~[0014] Certain~~Important~~ features have been broadly presented as to allow a better understanding of the detailed description that follows. ~~such that those skilled in the art may~~

~~appreciate the unique contributions and engineering concepts of the present invention.~~ It shall be understood by those skilled in the art that specific methods and structures described herein can~~may~~ be incorporated into differing designs that can~~may~~ be used to accomplish the same and/or similar objectives. It shall be understood that additional ~~objects~~advantages, if not set forth specifically herein, will be readily apparent to those skilled in the art from the following detailed description and from the drawings.

[0015] Advantageously, the present invention provides a high pressure electrocoagulation apparatus that incorporates the four mechanisms of disinfection and in so doing satisfies the requirements of a process to further reduce pathogens (PFRP).

Brief Description of the Drawings:

~~[0022]~~[0016] The preceding features and objects of the present invention and additional objects not listed herein may be clearly understood by those skilled in the art from the detailed description which follows and the drawings.~~, in which~~:

~~[0023]~~[0017] FIG. 1 is a schematic, block flow diagram of a preferred embodiment of the electrocoagulation method of the present invention.

~~[0024]~~[0018] FIG. 2 is four elevated views of a preferred embodiment of the ~~preferred~~ apparatus of the present invention

~~[0025]~~[0019] FIG. 3 is a horizontal cross section of the side view of a~~the~~ preferred embodiment of the apparatus of the present invention.

~~[0026]~~[0020] FIG. 4 is a front and side view of one embodiment of a right single recessed electrocoagulation spacer plate of the ~~preferred~~ apparatus.

~~[0027]~~[0021] FIG. 5 is a front and side view of one embodiment of a left single recessed electrocoagulation spacer plate of the ~~preferred~~ apparatus.

~~[0028]~~[0022] FIG. 6 is a view of one embodiment of an electrode of the ~~preferred~~ apparatus.

~~[0029]~~[0023] FIG. 7 is an isometric and front view of the influent mixing chamber/plate of one embodiment of the ~~preferred~~ apparatus.

~~[0030]~~[0024] FIG. 8 is an isometric and front view of the effluent mixing chamber/plate of one embodiment of the ~~preferred~~ apparatus.

~~[0031]~~[0025] FIG. 9 is a front and side view of a right double recessed electrocoagulation spacer plate of one embodiment of the preferred apparatus.

~~[0032]~~[0026] FIG. 10 is front and side view of a left double recessed electrocoagulation spacer plate of one embodiment of the preferred apparatus.

~~[0033]~~[0027] FIG. 11 is a horizontal cross section of three, single recessed electrocoagulation spacer plates through the line A-A' of FIG. 4 when ~~said~~the spacer plates are closed and held together with pressure.

~~[0034]~~[0028] FIG. 12 is a horizontal cross section of three, double recessed electrocoagulation spacer plates through the line B-B' of FIG. 9 when ~~said~~the spacer plates are closed and held together with pressure.

~~[0035]~~[0029] FIG. 13 is an isometric view of a plurality of electrocoagulation spacer plates of one embodiment of the ~~preferred~~ apparatus shown in a closed position without the supporting frame.

~~[0036]~~[0030] FIG. 14 is an isometric view of an external electrical buss bar attachment of one embodiment of the ~~preferred~~ apparatus.

~~[0037]~~[0031] FIG. 15 is a front and side view of an offset hexagonal electrocoagulation spacer plate of one embodiment of the ~~preferred~~ apparatus.

~~[0038]~~[0032] FIG. 16 is a view of an offset, hexagonal electrode of one embodiment of the ~~preferred~~ apparatus.

Description of the Preferred Embodiment

[0033] One preferred embodiment of the invention includes a plate and frame apparatus utilizing recessed, gasketed, non-conductive spacer plates with enclosed, exchangeable electrodes of various designs that are suspended on a supporting, square, elongate frame in such a way as to allow the spacer plates with electrodes to be easily separated or opened to exchange the electrodes or perform other maintenance and subsequently closed and pressured utilizing a hydraulic or screw type mechanical closure device that can maintain sufficient closure/operating pressure to seal the plurality of spacer plates with enclosed electrodes therefore containing pressured fluids within the confines of the plurality of chambers formed therein. The apparatus incorporates influent and effluent mixing chambers (containing injection ports for chemical reagents) in fluid communication with conduits, internal or external to the confines of the spacer plates and interconnecting influent and effluent piping allowing fluids to enter and exit the apparatus. Multiple mechanical separation means in fluid communication with the apparatus are used to subsequently separate liquids from liquids, liquids from solids and/or for dewatering of the fluid.

~~[0039]~~[0034] Referring to FIG. 1, fluids 110 collected in tank 100 are pumped through an interconnecting influent pipe 116 by means of a pump 115 to the high pressure, plate frame electrocoagulation apparatus 140. An actuated valve 125 is located in the interconnecting influent pipe 116 to contain fluids 110 in the collection tank 100 when the system is not in operation. Pump 115 is typically a centrifugal pump for low viscosity fluids and/or a progressive cavity pump for high viscosity fluids, slurries and/or sludge and is capable of variable flow rates and high pressures (10 to 225 psi). A riser pipe 138 is connected to the interconnecting influent pipe 116 at a higher elevation than the electrocoagulation apparatus 140 to collect any undissolved gas that may be present in the fluid 110 and venting ~~said~~the gas through pressure regulator valve 139 preventing any undissolved gas from entering the electrocoagulation apparatus 140. Gases are resistive to electrical current and reduce the electrical conductivity of influent fluids 110 inhibiting treatment. Pressure regulator valve 139 also provides passive pressure release in the event that unsafe pressures are encountered. Influent pressure of the fluid 110 is monitored by the pressure sensor 135 which transmits a variable signal proportional to ~~said~~the pressure to the controller 130. The controller may be a computerized PLC and/or other configured system utilizing analog and discreet inputs and outputs for data logging and activating automated devices. Two injection ports 126 are connected to the interconnecting influent pipe 116 for the addition of chemical reagents for desired oxidation reduction reactions and pressurized air for evacuating fluids from the electrocoagulation apparatus 140 when maintenance is required.

~~[0040]~~[0035] The electrocoagulation apparatus 140 is connected to a power supply 145 that provides an applied voltage to ~~said~~the apparatus. The applied voltage may be an alternating, direct and/or a pulsed current. The following examples describe~~For the purposes of this~~

~~discussion,~~ the applied voltage ~~shall be described~~ as a direct current ~~and~~with voltage applied to the terminal connections 128 of the electorcoagulation apparatus 140. As the pressured fluid 110 flows through the electrocoagulation apparatus 140 various reactions occur as described in ~~our~~ co-pending U.S. Patent application Ser. No. 60/244,615 and in the forthcoming details. As the pressurized fluids 110 exit the electrocoagulation apparatus 140, a preferred but not essential method step is the injection of a flocculent aid via injection port 127 to assist with subsequent separation methods. Pressurized fluids 110 exit the electrocoagulation apparatus 140 by means of the interconnecting effluent pipe 117 with attached temperature sensor 137 which monitors the temperature of the effluent fluids 110 and transmits a variable signal proportional to the temperature to the controller 130. The interconnecting pipe 117 is connected to an actuated pressure regulator valve 154 by raiser pipe 153 such that the elevation of the riser pipe 153 is higher than the electrocoagulation apparatus 140 and the subsequent separation means 150 and collects any undissolved gases that may be present in the pressurized fluid 110 and periodically purges ~~said~~the gases from the system to ensure that no undissolved gases enter the subsequent separation means 150. The pressure regulator valve 154 also provides passive pressure relief in the event that unsafe pressures are encountered. Pressure of the effluent pressurized fluid 110 is monitored by the pressure sensor 136 which transmits a variable signal proportional to ~~said~~ pressure to the controller 130. The pressurized fluid 110 may enter a variety of physical, mechanical and/or organic separation means 150 through pressure regulator valve 152 and pressure on the fluid 110 is dissipated as separation occurs by flotation, sedimentation, filtration and/or centrifugal force depending on the mechanism of the physical, mechanical and/or organic separation means 150. Treated fluid 110 exits the separation means 150 by means of a fluid conduit or pipe 118 connected to ~~said~~the separation means 150 by actuated valve 200. Separated

materials removed from the fluids 110 are collected in a holding vessel 159 for further disposition by a transfer pump 160.

~~[0041]~~[0036] FIG. 2 and FIG. 3 show four elevated views of a preferred embodiment of the high pressure plate and frame electrocoagulation apparatus 140 of the present invention. Together with FIG. 4, a horizontal cross section through the Z-axis viewing from the front of the head stock 122, details of the structure of the supporting frame become apparent to those skilled in the art. The supporting frame of the preferred apparatus comprises a rectangular, solid steel head stock 122 and tail stock 124 welded to two, heavy duty rectangular steel tubing side rails 142 perpendicular to ~~said~~ head stock 122 and tail stock 124 forming an elongate frame above grade for supporting, positioning and holding closure pressure on a plurality of electrocoagulation spacer plates 300, hereafter referreed to as ES-P's ~~(ESP's are defined in the objects of the present invention and shall be discussed in detail in the forthcoming text)~~. The ESP's 300 ride on the top of the side rails 142 of the supporting frame and ~~may~~can be separated or opened for accessing internal components and subsequently closed and pressured by the hydraulic closure mechanism 144 that is integrally attached to the tail stock 124 and the push plate 146. The push plate 146 also rides on top of the side rails 142 and is held in a perpendicular position by two rollers 148. In one embodiment, a~~A~~ spool piece 147 ~~may or may not be~~is included to allow for future expansion, different configurations of the apparatus ~~and/~~or incorporation of multiple power supplies by segregating groups of ESP's 300.

~~[0042]~~[0037] The head stock 122 of the preferred apparatus is constructed of solid steel providing a supporting leg for the apparatus and a means for attachment of the two side rails 142. Electrical contact terminals 128 are inserted through two ports 311 near the top of the head stock 122 providing a means for the applied voltage supplied by the power supply 145 to contact

internal components. The external electrical contact utilizes standard explosion proof conduit-junctions that are familiar to those skilled in the art. Two through wall ports 121 are located near the bottom corners of the head stock 122 and are in fluid communication with internal, effluent conduits 149 providing a means for fluids 110 to exit the apparatus. Although only two effluent ports 121 are shown, more may be utilized determined by the application. The two effluent ports 121 are connected to an effluent manifold 123 which is in fluid communication with the interconnecting effluent pipe 117. Effluent temperature sensor 137 and effluent pressure sensor 136 are located in the interconnecting effluent pipe 117 to monitor temperature and pressure of the pressurized fluid 110 as it exits the apparatus and transmit variable signals proportional to the temperature and pressure to the controller 130. The interconnecting influent pipe 116 is in fluid communication with the influent feed pump 115 (FIG. 1) and incorporates actuated valve 125 used for segregating the system from the collection tank 100 and allowing the apparatus to be depressurized by opening pressure regulator valve 139 and/or pressure regulator valves 154 and 152 (FIG. 1). Integral with the influent interconnecting pipe 116 are two injection ports 126 for the addition of chemical reagents that may or may not be utilized for oxidation reduction and/or other desired reactions, and air for blowing down the apparatus to evacuated fluids 110 from the apparatus prior to or during depressurization and subsequent opening for inspection and maintenances. A riser pipe 138 is connected to the influent interconnecting pipe 116 behind the injection ports 126 and before the influent conduit 325 through the head stock 122 providing a means of collecting any gases not in solution and purging ~~said~~the gases to the collection tank 100 to avoid inclusion of ~~said~~the gases in the influent pressurized fluid 110 avoiding a reduction of electrical conductivity in the influent fluid 110. Integral with the riser pipe 138 are pressure regulator valve 139 and influent pressure sensor 135 which monitors influent fluid 110 pressure

and transmits a variable signal proportional to ~~said~~the pressure to the controller 130. Pressure regulator valve 139 also provides passive pressure relief by receiving a signal from the controller 130 to open when a pre-set, limiting pressure is detected thereby avoiding an unsafe condition.

~~[0043]~~[0038] The tail stock 124, like the head stock 122, also provides a support leg for the apparatus and a means of welded attachment for the two side rails 142. The tail stock 124 also provides a means of supporting the integrally attached hydraulic closure mechanism 144 for opening, closing and maintaining pressure on the closed stack of ESP's 300. The hydraulic closure mechanism 144 is an air operated closure mechanism lockable in the closed position that is capable of maintaining sufficient closure pressure to allow influent pumping and operating pressure of the fluid 110 at 110 psi. Closure pressure is in direct~~ly~~ correlation ~~correlatable~~ to the cross sectional surface area of the ESP 300 stack and will vary with the size of the preferred apparatus. All hydraulic components and a local control panel 220 are integral with and enclosed within the tail stock 124 and include pneumatic and hydraulic pressure relief bypass means (not shown) to avoid damage to the apparatus in a malfunction condition. All integral, internal hydraulic components, air headers, pumps, air regulators etc. are accessible to the operator through an access door 143 in the tail stock 124.

~~[0044]~~[0039] FIG. 5, 6, 10, and 16 show front and side views of ESP's of the preferred apparatus and together with FIG. 14, an isometric and cross-sectional view of a plurality of ESP's shown in a closed position without the supporting frame, and FIG. 7 and 17, views of electrodes 141 of the preferred apparatus, the mechanism of fluid 110 transport through the apparatus and distribution of the applied voltage throughout the apparatus will become apparent.

~~[0045]~~[0040] Electrocoagulation spacer plates~~LECTROCOAGULATION SPACER PLATES~~ ~~(~~300~~), hereafter referred to as ESP's,~~ are advantageously ~~defined as~~ flat, recessed, gasketed, ported devices constructed of non-electrically conductive materials including~~comprising~~ an internal cavity 305 for supporting and containing various shaped electrodes 141 within confined boundaries such that when a plurality of like devices is stacked together, an internal, elongate cavity 221 with multiple, parallel tubular conduits is isolated within. ESP's are typically square and/or offset hexagonally shaped. FIG. 14 is an isometric view of a plurality of ESP's 300 stacked together without a supporting frame or electrodes 141 showing the internal elongate cavity 221 and surrounding parallel conduits 222 within. When flat, ported electrodes 141 are enclosed within the recessed boundaries 224 of the closed ESP's 300, a plurality of perpendicular chambers 223 is isolated within the internal, elongate cavity 221 such that fluids 110 may flow through a path established~~dictated~~ by the shape and location of any openings in the flat, enclosed electrodes 141. In this illustration the preferred shape and location of ~~said~~the openings are rectangular ports 226 located at alternating ends therefore dictating a meandering or sinuous path. ~~Said~~The ports may be circular, rectangular, etc. and may be located at alternating tops and bottoms of electrodes 141, at alternating right and left sides of electrodes 141 and/or any combination of ~~said~~the locations as to advantageously develope~~dictate~~ a meandering or sinuous flow pattern and/or a spiral or conical flow pattern. When an applied voltage is connected to the terminals 128 of the apparatus and distributed throughout the apparatus such that alternating positive (+) and negative (-) electric potentials are realized by the enclosed electrodes 141 while fluids 110 are flowing through the ~~dictated~~ sinuous path, an electric current flows from electrode 141 to electrode 141 and therefore through the pressurized fluid 110 circulating through the apparatus.

~~[0046]~~[0041] The means of distributing the applied voltage throughout the apparatus is accomplished by interconnecting, metallic inserts 310 that are embedded and/or inserted in the upper, gasketed ports 301 of the ESP's such that when a plurality of ESP's 300 are closed and held together ~~said~~the metallic inserts 310 contact each other, the power contact 303 of selected electrodes 141, and the electrical terminal contacts 128 located at the head stock 122, thereby defining a continuous electrical conduit (FIG.4/312) and a complete circuit for distribution of electrical power. All ports 301 and~~&~~ 304 within the body of the ESP's 300 are individually contained by port gaskets 302 that are inserted into grooved recesses such as to hold ~~said~~the port gaskets 302 in place and seal ~~said~~the ports 301 and 304 containing and isolating same from fluid intrusion as with upper electrical ports 301 and/or fluid extrusion as with the case of the lower fluid ports 304 used for effluent fluid conduits 149 (FIG. 4) formed when a plurality of ESP's are closed and held together. A peripheral gasket 307 is positioned within a like~~-~~recessed groove located around the outer perimeter of the ESP's 300 thereby containing all internal cavities 305, all gasketed ports used for electrical purposes 301, metallic inserts used for electrical conduits 310, all gasketed ports used as fluid conduits 304, and pressured fluids 110 within the confines of ~~said~~the peripheral gasket 307 and ESP's 300 isolating same from the outside environment. ESP's may or may not be single recessed FIG. 5 and FIG. 6 meaning that the internal recessed boundary support 224 with rectangular recession 306 for location of selected electrode power contact 303, is located on only one surface for enclosing and positioning of one electrode 141 and/or double recessed FIG. 10 and meaning that the ESP's 300 contain internal recessed boundary supports 224 on both surfaces for enclosing and positioning of two electrodes 141. A double recessed ESP 300 may be utilized with one powered electrode 141, using the second recessed boundary support 224 to position a non-powered baffle surface creating a longer fluid

path within the apparatus for (1) increasing the dwell time (reaction time) that the fluid 110 being treated is exposed to the electromotive force present within the apparatus and (2) increasing the distance between powered electrodes 141 requiring a higher applied voltage resulting in increased electrolysis and increased release of oxygen (O2) and hydroxyl (OH-) ions available in solution for oxidation reduction reactions. When a non-powered baffle plate is incorporated in the second recessed boundary support 224 of a double recessed ESP 300, ~~said~~the baffle plate is held in position by pins 315, inserted parallel to the outer surface of ~~said~~the baffle plate and perpendicular to the recessed boundary support 224 edge (FIG. 10). The extended, rectangular recession 306 that is integral with the internal recessed boundary support 224 for contacting selected electrodes 141 may be located in the right position as shown in FIG. 5 or in the left position as show in FIG. 6 to receive the electrode power contact 303 of selected electrodes 141. ESP's 300 rest vertically within the two side rails 142 of the supporting frame by means of a slotted, integral support 308 using the rectangular shaped slot 309 for positioning and alignment on the rectangular tubing of ~~said~~the side rails 142.

~~[0047]~~[0042] FIG. 8 is an isometric and front view of an influent mixing chamber plate 320 (the isometric view omits integral supports) that may or may not be attached to the head stock 122. It is comprised of many like features in that there are two upper gasketed ports 301 used to contain metallic inserts 310 and two, lower gasketed ports 304 used for fluid transport, but this device does not contain and position any electrodes 141. The influent mixing chamber plate 320 has a centrally located influent conduit 325 that protrudes through the influent port 151 in the head stock 122 and is in fluid communication with the interconnecting influent pipe 116 thereby allowing pressurized fluids 110 to enter the apparatus. It is a hollow structure with internal baffles 321 oriented such that the fluid 110 direction is reversed when traversing through the

chamber, agitating ~~said~~the fluid 110 to mix any chemical reagents that may be injected via the injection ports 126 in the interconnecting influent pipe 116. There is a rectangular port 322 located at the bottom of the back wall 323 to allow the pressurized fluid 110 to flow through. All tubular ports 301 and 304 extend from the front wall 324 to the back wall 323 isolating same from the internal chamber between. The influent mixing chamber plate 320 is constructed of non-electrically conductive materials and isolates electrical contact with the head stock 122 and side rails 142 like ESP's 300.

~~[0048]~~[0043] FIG. 9 is an isometric and front view of the effluent mixing chamber plate 330 (the isometric view is shown without integral supports). The effluent mixing chamber~~It is so named because it~~ receives fluid flow through the influent, rectangular port 335 located on the upper portion of the front surface 331 and redirects fluid flow to the head stock 122 of the apparatus via the two gasketed fluid ports 304 located at the bottom inside surface 331. The lower, gasketed, fluid ports 304 align with like-gasketed ports 304 in adjacent chambers thereby ~~comprising~~creating a continuous fluid conduit 149 (FIG. 4) within confined boundaries isolated from the outside environment. An injection port 127 is located at one side where fluid flow is reversed by one of two internal baffles 332 for injection and flash mixing of a flocculent aid and/or chemical reagents. The back surface 333 of the effluent mixing chamber plate 330 is contacted by the push plate 146 which is connected to the hydraulic closure mechanism 144 providing closure pressure for the apparatus. Like the influent mixing chamber plate 320, the effluent mixing chamber plate 330 contains no electrode 141. In one embodiment, the influent mixing chamber plate~~Its~~ is advantageously provided~~purpose is~~ to redirect fluid flow to the head stock 122, provide an injection means 127 for flocculent and/or chemical reagents and mix same

via internal baffles 332, provide a means of contact to the push plate 146 and provide a means of electrical insulation to the supporting frame.

We claim:

1. An apparatus and system ~~that uses an improved design~~ for the high pressure electrocoagulative treatment and subsequent removal of undesirable matter and organisms in suspension, in solution and/or in a stable state of emulsion in aqueous and viscous fluids and sludge comprising:

(a) A plate and frame design utilizing hydraulic or screw type mechanical closure and pressure on a plurality of recessed, gasketed, non-conductive spacer plates that completely or partially enclose square, rectangular, offset pentagonal and hexagonal or rod shaped electrodes in such a way as to form chambers through which an aqueous and/or viscous fluid may flow and may or may not come into contact with the electrode surfaces and also be exposed to the electromotive force present therein;

(b) Applying a voltage to said electrodes in such a way on said electrodes to produce an alternating sequence of positive and negative electric potentials and thus causing a continuous flow of electrical current through the aqueous and viscous fluid flowing through said chambers;

(c) Reacting with undesirable matter and/or organisms present in suspension, in solution and/or in a stable state of emulsion in the aqueous and/or viscous fluid with material sacrificed from the electrode surfaces and/or the electromotive force produced by said applied voltage within the apparatus in such a way as to cause the destabilization of colloidal particulates and/or emulsions, the direct chemical replacement and precipitation of substances, the co-precipitation of substances and/or disrupting the osmotic interchange of fluids through permeable, semi-permeable and/or other membrane boundaries of undesirable living organisms such as bacteria, viruses and/or cysts therefore causing the implosion or explosion of said organisms rendering them harmless to humans, animals, insects, vegetation and/or the environment;

(d) A physical, mechanical and/or organic separation means in fluid communication with said apparatus via a conduit with a pressure release valve located at the point of entry to the said separation device such that pressure is maintained within the apparatus and

the conduit such that any evolved ~~gasses~~gases ~~shall~~can be maintained in solution within the apparatus and the conduit such that said non-evolved gases ~~shall~~can be available for oxidation/reduction reactions with matter and/or organisms in solution, in suspension and/or in a stable state of emulsion in the aqueous and/or viscous fluid;

(e) Said physical, mechanical and /or organic separation means is preferably (1) a dissolved air/gas flotation chamber as utilized for aqueous fluids such as water and wastewater, (2) a two phase and/or three phase decanting centrifuge as utilized for the disinfection (destruction of pathogens) and subsequent dewatering of biological sludge, liquefied manure and/or the separation of oil, water and solids, (3) a membrane concentration system and/or membrane bioreactor as utilized for concentrating and/or elimination of organic substances, (4) hydro cyclones as utilized for soil slurries and oilfield drilling fluids, (5) a rotary and/or belt press as utilized for dewatering biological sludge and/or (6) a plate and frame filter press as utilized for dewatering of hazardous sludge.

(f) An apparatus and system as recited in claim (1), wherein the hydraulic or otherwise screw type mechanical closure pressure on the recessed, gasketed,, non-conductive spacer plates with electrodes is greater than the influent pumping pressure of the aqueous and/or viscous fluid being pumped through the apparatus such that the apparatus contains all fluids and substances within the confines of the chambers formed by the recessed, gasketed, non-conductive spacer plates;

Question: Do we need to claim slots at alternating ends of electrode plates such that a serpentine or sinuous path is followed by the fluid?

2. An apparatus and system as recited in claim (1) wherein the recessed, gasketed, non-conductive spacer plates posses integral supports on the edges such that the spacer plates with enclosed electrodes ~~shall~~can rest on the side rails of a square or rectangular elongated frame and are free to be opened and closed for electrode replacement and/or other maintenance of the apparatus;

3. An apparatus and system as recited in claim (1) that includes baffled influent and baffled effluent chambers and/or plates at both ends that may or may not be integral with the square or rectangular elongated frame for; <1> the addition and flash mixing of chemical reagents and/or flocculants and <2> also provides a means of fluid communication to an influent and/or effluent conduit that may or may not be within the confines of the gasketed spacer plates for aqueous and/or viscous fluids entering or exiting the apparatus.

4. An apparatus and/or system as recited in claim (4) wherein the effluent fluid conduit is formed by the interconnection of gasketed ports in the recessed, gasketed, non-conductive spacer plates.

5. An apparatus and/or system as recited in claim (5) (or claim 1-?) wherein the means of dispersing the electrical current to the electrodes and throughout the apparatus is accomplished by an internal electrical conduit that is formed by metallic inserts embedded within the confines or inserted thru gasketed ports of the recessed, gasketed non-conductive spacer plates in such a way that they contact each other and the enclosed electrodes forming a continuous electrical conduit when closure pressure is applied to a plurality of spacer plates with enclosed electrodes;

6. An apparatus and/or system as recited in claim (6) (or claim 1) wherein offset, hexagonal electrodes may be larger than the recessed, gasketed, non-conductive spacer plates such that the exposed, edges of the electrodes may be connected to an external, flat buss bar by means of integral, flat clamps that snaps onto and off of the exposed edges of said electrodes thus providing a less expensive, easily maintained configuration that may be used in non-explosive environments;

7. An apparatus and system as recited in claim (7) wherein the recessed, gasketed, non-conductive spacer plates are in the shape of an offset pentagram and/or hexagram, such that the edges of the larger electrodes may be exposed in such a way as to allow a flat buss bar with integral clamps to snap onto and off of the exposed corners or edges of the electrodes.

8. An electrocoagulation spacer plate hereby defined as a recessed, gasketed, non-electrically conductive, usually square or offset hexagonally shaped plate of sufficient thickness that may (1) contain a variety of shaped electrodes within a recessed boundary such as to hold

and position said electrodes in a specific orientation, (2) contains multiple, integral, gasketed ports that ~~shall~~can align with like gasketed ports in adjacent spacer plates on either side forming internal fluid conduits perpendicular to the vertical axis of said spacer plate when a plurality of said spacer plates are closed and held together, (3) contains multiple, integral, gasketed ports that ~~shall~~can align with like gasketed ports in adjacent spacer plates on either side containing metallic inserts embedded or inserted in said ports, that ~~shall~~can contact other said metallic inserts and/or enclosed electrodes therein forming a continuous electrical conduit perpendicular to the vertical axis of said spacer plate when a plurality of said spacer plates are closed and held together and (4) contains a peripheral gasket near the outer perimeter of said spacer plate that surrounds and contains all enclosed electrodes and all enclosed, gasketed fluid and electrical conduits within the confines of said spacer plate when a plurality of said spacer plates are closed and held together therefore isolating said electrodes, fluid conduits, electrical conduits, fluids and other matter and substances from the outside environment. Said electrocoagulation spacer plates may or may not be recessed and gasketed on one and/or both sides and have slotted, positioning supports integral to the edges that rest on the side rails of a square and/or rectangular, elongated frame.

ABSTRACT

~~[0049]~~[0044] The present invention introduces method and apparatus comprising an improved design for the high pressure electrocoagulative treatment of aqueous and viscous fluids and sludge. The apparatus is configured as a plate and frame design utilizing hydraulic or screw type mechanical closure on a plurality of recessed, gasketed, non-electrically conductive electrocoagulation spacer plates, hereafter referred to as spacer plates, that completely enclose and isolate all fluids, electrical contacts, and electrodes within the confines of the apparatus. The spacer plates include integral supports on their edges that position and support said spacer plates with enclosed electrodes on top of the side rails of the supporting frame of the apparatus allowing said spacer plates to be separated for electrode replacement and maintenance and conversely closed, pressured and put into service. The apparatus also includes a baffled influent and effluent chamber at both ends for the addition and flash mixing of chemical reagents and/or

flocculants and that provide a means of fluid communication between fluid conduits and chambers formed within the apparatus by the interconnection of gasketed ports and cavities located in the spacer plates and external conduits thus allowing fluids to enter and exit the apparatus. Various physical, mechanical and/or organic separation means are utilized determined by influent fluid characteristics and the desired goals and objectives of treatment.